# USER'S MANUAL

# ENERGY PLANNERS' SOFTWARE PACKAGE
# [EPSP]

(IBM/PC Based Programs for Energy Planners
in Developing Countries)

Developed by

TATA ENERGY RESEARCH INSTITUTE, NEW DELHI

for

ECONOMIC AND SOCIAL COMMISSION FOR
ASIA AND THE PACIFIC
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## ENERGY PLANNERS' SOFTWARE PACKAGE

### PROJECT TEAM

Project Co-ordinator
Dr. Veena Joshi

Programmer
Mr. M. Karuppasamy

Technical formulation for different modules was prepared by

| | | |
|---|---|---|
| * TERI Energy Economy Simulation and Evaluation (TEESE) Model | : | Ms.Leena Srivastava |
| * Resource Allocation Model | : | Ms.Leena Srivastava |
| * Rural Energy Model | : | Ms. Charu Gadhok |
| * Evaluation of Renewable Energy Technologies for End uses | :<br>: | Mr. Kapil Thukral and<br>Dr. Veena Joshi |
| * Energy Conservation in Buildings | : | Dr.V.V.N. Kishore |

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# PREFACE

Within the Regional Energy Development Programme (REDP) of the Economic and Social Commission for Asia and the Pacific (ESCAP) Sub Activity A-3.1 has been identified as dealing with "Assistance to two LDCs in Strengthening Overall Energy Planning and Policy Analysis Capabilities and Master Plans". The activity proposed in the REDP required the development of a suitable Training Manual with appropriate software to be used in training of officials from the LDCs identified for this activity. The executing agency for this activity is the United Nations Educational, Scientific and Cultural Organisation (UNESCO), and in turn the work was sub-contracted to the Tata Energy Research Institute (TERI) which is the lead institution in Asia for the Cooperative International Network for Training and Research in Energy Planning (CINTREP), the Secretariat of which is at UNESCO, Paris.

The contract for execution of this work was signed between UNESCO and the Tata Energy Research Institute on the 2nd of September, 1985. Accordingly the following tasks have been attempted and completed as required:

1. Selection and recommendation of an appropriate microcomputer for use in the proposed training programme to be organised by ESCAP.

2. Preparation of an Energy Planning Training Manual as detailed on the contents page along with corresponding software.

The Training Manual detailed and described in these pages deals with a range of microcomputer-based methodologies and techniques that are essential for advancing and understanding of energy planning in the LDCs. The software developed for the purpose is used as the basis for the Training Manual so that participants in the training programmes can get "hands on" experience in the use of microcomputers and software developed in this project.

The Manual has been written in a user-friendly manner so that with the minimum of effort officials from the countries concerned can gain familiarity rapidly in the use of software and hardware to be utilised for the purpose.

We believe that the work done in this Manual represents a major advance in the application and use of microcomputers and related energy planning methodologies in the developing countries.

R.K. Pachauri
Director
Tata Energy Research Institute
New Delhi

# 1. INTRODUCTION

Developments in computer hardware over the last decade have resulted in availability of powerful microcomputers to a larger cross-section of professionals in all fields. In developed countries, most professionals own a micro while in developing countries most organisations are in a position to own one. As a result of this, it is now possible to carry out analysis which was earlier carried out with long waiting periods on large computers in exclusive organisations. Full utilisation of the easy and quick access to powerful computational capabilities of these micros depends on the availability of user friendly software in different areas. The Tata Energy Research Institute undertook a project to develop and compile different software modules useful in the field of energy planning and to be used as training material for energy planners.

The Energy Planners' Software Package (EPSP) consists of six independent modules; viz.

1. TERI Energy Economy Simulation and Evaluation (TEESE) Model : This model is a tool for analysing and evaluating energy policy options for a country in an integrated manner. It is a linear programming model and accounts for the linkages between energy and non-energy sectors by representing the energy flows in the economy in terms of efficiencies of conversion,

losses at various stages and processes. It also predicts the economic implications of these flows in terms of costs and benefits.

2. **Elasticity Estimation Model :** This package is useful in estimating elasticities. It is an interactive statistical package where a linear, log-linear or log-log multiple regression analysis can be carried out.

3. **Resource Allocation Model :** This simulation package is developed to study interactions within an economy and is illustrated for India. Equations obtained in the statistical package are utilised here.

4. Rural Energy Model : This is a linear programming model developed for rural energy planners to assist in village or community level planning. It aims to find the most suitable mix of resources and technologies to cater to the needs of the village. It can be used as a framework for the analysis of alternative technologies within a specified time horizon and constrained budgets.

5. **Evaluation of Renewable Energy Technologies for different End Uses :** This module looks at the economics of renewable energy technologies like biogas gasifier and solar for end uses such as cooking, water heating , irrigation etc.

6. **Energy Conservation in Buildings :** In all developing countries large construction activities are being planned. Hence energy conservation in buildings using renewable energy techniques and better designs becomes very important. This module illustrates a methodology to calculate heating load for a building; it also evaluates the impact of various building strategies including solar gain on this heating load.

All these modules are designed to be user friendly and interactive. They are developed on the IBM/PC and are capable of execution on other micros in IBM/PC series and their compatible micros. They can be used as analytical tools in different stages of energy planning.

Section 2 gives general instructions to the user to get started with the EPSP. The user's manual then describes each of the modules in separate sections along with instructions on how to use them.

## 2. GETTING STARTED

**2.1 Computer Facility Requirements:** The Energy Planners' Software Package is developed to run on the IBM/PC, XT or AT with the 80287/8087 math co-processor, minimum memory of 256 Kbytes, a monochrome terminal, two drive system, or a drive and a hard disk, and a printer. Software requirements for this package are:

(i) PC-DOS/MS-DOS Operating System
(ii) LOTUS 1-2-3
(iii) LP83 Package of Sunset Software

The EPSP can also be run on an IBM/PC compatible machine using PC-DOS/MS-DOS operating system.

**2.2 Conventions used in the Manual:** Unless otherwise specified, this manual uses the following symbolic conventions.

| Convention | Description |
|---|---|
| < > | Angle brackets enclose the variable name or the name of key on the key board. |
| ( ) | Parentheses enclose a list from which an item is chosen. |
| o o o | Horizontal ellipses indicate that the preceding item may be repeated one or more times. |
| o<br>o<br>o | Vertical ellipses indicate that irrelevant parts of a figure or example have been omitted. |
| ¶ ¶<br>¶ ¶ | Screen display is enclosed by two horizontal lines with vertical ends. |

| | |
|---|---|
| ==> XXX | indicates the module message or prompt on the screen. |
| XXXXXXXX<R> | indicates responses to be entered by the user. <R> represents return key. And this key is marked as ↵ on IBM/PC series computer. |

A typical question and response will therefore appear like :

==> Enter file name? FILEOUT <R>

2.3 Precautions in Handling the System and Software: You need to be familiar with performing the following operations before using EPSP.

i) To switch on the system.

ii) To load and unload diskettes.

iii) Working knowledge of MS-DOS/PC-DOS.

iv) Idea of file organisation on diskettes.

v) Knowledge of LOTUS 1-2-3 and LP83 by Sunset Software is needed for TEESE model and rural energy model.

2.3.1 Master Copy Organisation: You are provided with two master floppies marked as : TERI-ESCAP MASTER-I and TERI-ESCAP MASTER-II

These copies are to be used as MASTER BACKUP and are write protected i.e. you can only read from these copies and cannot write on them either in existing files or in new files. This is a safeguard to maintain EPSP in its original form.

Table 2.1 : Organisation on Master Floppies

| MASTER Floppy | Module | Related Files |
|---|---|---|
| MASTER I | 1. TEESE Model | IOMODEL.EXE<br>TRIAL.WKS |
| | 2. Rural Energy Model | FREM1.WKS |
| MASTER II | 3. Elasticity Estimation Model | STATANA.EXE<br>STATANA.JOB |
| | 4. Resource Allocation Model | RESOURCE.EXE |
| | 5. Technology End use Package | TECHUSE.EXE<br>TECHUSE.OVR |
| | 6. Building Model | BUILDING.EXE |

### 2.3.2 Making Working Copies:

If you have one floppy drive and one hard disk on your computer:

Copy all the files from the two master floppies to the hard disk. To do this, follow the steps given below:

1. Load MASTER I in A-drive
2. Type COPY A:*.* C:<R>

Now all the files on the MASTER I floppy are transferred to the hard disk. Repeat the same procedure to copy files from MASTER II to the hard disk. The files on the hard disk constitute your working copy of the EPSP.

**If you have two floppy drives and no hard disk:**

In the absence of the hard disk,to avoid confusion, you are advised to make working copies on different floppies for different modules.

To do this, follow the steps given below:

1. Load MASTER II in A-drive
2. Load an empty formatted floppy in B drive
3. Copy all the files in a module in MASTER II by typing the following command for each file in the Package. (Ref. Table 1.1)

```
COPY A:<filename>B:<R>
```

4. Make sure that all the files in the module are copied, this can be done by displaying the directory of files on floppy in B drive using the command, `DIR B:`
5. Take out the floppy from B drive and label it with the appropriate title eg: ELASTICITY ESTIMATION PACKAGE (WORKING COPY)

Repeat the same procedure to make working copies for all the modules on both the Master floppies. Now you are ready with the working copies of EPSP.

**For all users:**

After making the working copies for all the modules, keep the master copies in a safe place.

**2.4 Manual Design:** The six modules in EPSP are described separately in sections 3 to 8. Besides explaining data requirements and giving instruction to execute a module, in some cases a sample output is also provided. The technical formulation for each module is briefly described and its capabilities and limitations are discussed.

# 3.TERI ENERGY ECONOMY SIMULATION AND EVALUATION (TEESE) MODEL

3.1 Introduction: The TEESE model is a computerised model to study energy economy interaction for India. It can be used as a tool for evaluating, in the medium term, the effects of postulated or assumed changes in the energy system on the economy as a whole. Following is the list of applications of the present model:

- Useful tool for forecasting
- Study of substitution possibilites
- Comparison of investments in energy sector vis-a-vis investments in non-energy sector
- Identification of high potential conservation areas
- The shadow prices generated by the LP represent marginal values and provide useful policy guidelines.

3.2 Model Structure: The model can be looked upon as consisting of three separate parts (i) the Reference Energy System (RES) (ii) the Input-Output (I/O) framework and (iii) the Linear Programming (LP) problem. The main features of this model are:

- it provides a simplified mathematical representation of the energy flows in the economy.
- it accounts for conversion losses, transmission and distribution losses in the structure of the I/O model.
- it includes a linear programming part that draws upon the I/O model. The accounting equations of the latter form the bulk of the constraints for the former.
- while it is essentially static in nature it has the flexibility to upgrade the coefficient matrix with relative ease as well as to include/exclude additional

sectors. It is a very valuable tool for providing policy guidelines to decision makers.

3.2.1 **Reference Energy System:** Figure 3.1 is an example of a typical RES and is presented here for illustrative purposes. It provides a graphical representation of India's energy balance for 1972. The first column in the RES denotes resources and the last one the demand sectors of the economy. Energy flows from a resource to a demand sector through extraction, refining and conversion and other stages are traced by taking into consideration energy losses at each stage. Conversion efficiencies are given in brackets. Dotted lines in the RES imply that the stages indicated by the column headings do not apply to the resource under consideration. The specification of end use demands in the RES should ensure sectoral consistency and this is done with the help of the I/O model described below.

3.2.2 **Input-Output Model:** The standard Input-Output notation is

$$AX + Y = X \qquad \text{--------} \ (i)$$

where,

A = Matrix of inter-industry co-efficients

X = Vector of gross outputs

Y = Vector of final demands

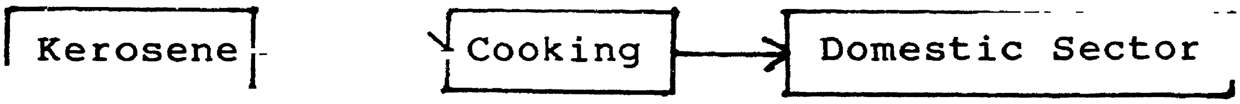
Equation (i) can also be written as

$$X = (I-A)^{-1}Y \qquad \text{--------} \ (ii)$$

and can be used to calculate gross outputs for changes in final demands or in industry coefficients. Conventionally, construction of the A matrix is done by using the transactions matrix T which quantifies the actual interindustry flows in physical units. Each column of this table gives the input requirements of the particular industry while the corresponding row total gives the total value of output. The division of the column entries by the corresponding row total yields the A matrix.

The planning bodies of most countries publish an Input-Output model for the economy as a whole. Similarly, the Input-Output model for India for the year 1979-80, published by the Planning Commission, was used by us as the basic building block for this part of the model. The non-energy sector flows from the Planning Commission's I/O table, denominated in monetary terms, were extracted to form the the Input-Output table for the non-energy sector.

The energy flows are drawn such that they conform to the definition of the non-energy sectors provided by this latter table. The flow from the energy supply sectors to the non-energy sectors is routed through energy products. In other words, energy sources are first converted into the end uses into which they are going by means of either device efficiencies or by looking at relative Input/Output efficiencies in those cases where there is more than one process. For example, kerosene consumed by the domestic sector is first converted to the end-use to which it is being put and would be represented as :



Accordingly, in eqn . (i) the final demands and the gross outputs vector are partitioned to reflect energy supply, energy products and non-energy demands and outputs with the use of subscripts s, p and i respectively, we would have

$$X = \begin{bmatrix} Xs \\ Xp \\ Xi \end{bmatrix} \begin{array}{l} = \text{output vector for energy supply} \\ = \text{output vector for energy products} \\ = \text{output vector for non energy sectors} \end{array}$$

$$Y = \begin{bmatrix} Ys \\ Yp \\ Yi \end{bmatrix} \begin{array}{l} = \text{final demand for energy supply} \\ = \text{final demand for energy products} \\ = \text{final demand for non energy sectors} \end{array}$$

Table 3.1 in Appendix 3.1 lists out all the energy supply, energy product and non-energy sectors giving values for gross output and final demands of these sectors for the year 1979-80. While exports of energy would appear in the Ys vector the energy demands of domestic consumers and the Government would appear in the Yp vector.

Eqn. (i) can then be written as

$$\left.\begin{array}{lllllll} AssXs & + & AspXp & & + & Ys = Xs \\ ApsXs & + & & + \; ApiXi & + & Yp = Xp \\ AisXs & & & + \; AiiXi & + & Yi = Xi \end{array}\right) \text{------ (iii)}$$

The coefficients matrix A can then be artificially partitioned and would look as:

$$A = \begin{array}{ccc|l}
\text{Energy Supply} & \text{Energy Product} & \text{Non-Energy} & \\
\hline
\text{Ass (Kcal/Kcal)} & \text{Asp (Kcal/Kcal)} & 0 & \text{Energy Supply} \\
\text{Aps (Kcal/Kcal)} & 0 & \text{Api (Kcal/Rs)} & \text{Energy Product} \\
\text{Ais (Rs/Kcal)} & 0 & \text{Aii (Rs/Rs)} & \text{Non-energy}
\end{array}$$

Where,

Ass: input-output coefficients describing sales of the output of one energy supply conversion sector to another energy sector and conversion losses incurred in producing or distributing energy. Conversion losses may be excluded if all coefficients are calculated on the basis of delivered energy.

Asp: input-output coefficients describing how distributed energy products are converted to end-use forms. They contain the end-use conversion efficiencies embodied in the RES.

Asi: 0 implying that energy supplies are not used by non-energy producing sectors; energy is distributed to the non-energy-producing sectors via energy product sectors.

Aps: input-output coefficients describing how energy products - final energy forms - are used by the energy supplying industries. For example, electricity use for lighting a refinery would be included here.

Aps: 0 implying that energy products are not used to produce energy products.

Api: input-output coefficients describing how energy products - final energy forms - are used by non-energy producing sectors. This submatrix describes the ways end-use energy forms are used in the non-energy producing sectors.

Ais: input-output coefficients describing the uses of non-energy materials and services by the energy industry. An example of this would be requirements of machinery for oil drilling or coal mining.

Aip: 0 implying that energy product-sectors equipment require no material or service inputs. This is because they are pseudo-sectors and not real producing sectors.

Aii: input-output coefficients describing how non-energy products are used in the non-energy producing sectors. Coefficients in this submatrix are enumerated in purely monetary terms. Aii is equivalent to the A matrix of the conventional input-output framework.

The non-zero coefficient submatrices are shown in Tables 3.2 to 3.6 in Appendix 3.1. Note that the Ais block ensures that the non-energy sector output remains consistent with energy sector output, the Aps block ensures that energy inputs to energy supply are accounted for and the Api block ensures that energy demands are proportioned to the sectoral outputs. The equivalence of the six non-zero blocks of the A matrix with the RES is also given in figure 3.1.

The entire I/O system is driven by the vector of final demands (Yi) from the set of equations (iii) (which can be represented in the form of equation (ii)). Thus, given a certain change in any or all of the elements of the Y vector, the impact on the rest of the economy can be quantified through the product $X = (I-A)^{-1} * Y$ assuming a fixed level of technology.

Impacts of a technical change can be estimated by making appropriate changes in T matrix. This would involve the inversion of the matrix (I-A) and its multiplication with the Y vector to obtain gross output vector X.

**3.2.3 Linear Programming Model:** The RES is viewed as a network optimisation problem in which energy flows are routed through a linear network such that some objective function is optimised, subject to the requirement that all end use demands are met. The objective function is specified as the minimisation of energy system costs :

$$\min \quad S = CX = \sum_i C_i X_i \quad \text{----------(iv)}$$

where C is a vector of unit costs and X is a vector of optimal energy required due to, say, the ith source i.e., cost for generating one unit of energy supply due to a source. The constraints set can be written as

$$\begin{aligned} G_1X_1 &= D \\ G_2X_2 &<= S \qquad \text{----------(v)} \\ G_3X_3 &= 0 \end{aligned}$$

where D is a vector of end-use demands, S is a vector of supply constraints and the third equation represents all other network balances. The Gi represent corresponding coefficient matrices.

The Input-Output model explained above can be appended to this LP in a relatively simple manner. The vector of end-use demands (D) would decompose into intermediate energy demands of both the energy supply and non-energy sectors ApsXs + ApiXi plus the vector of final demands Yp. The entire set of constraints would now look as

$$G_1X_1 = ApsXs + ApiXi + Yp \text{ or}$$

$$G_1X_1 - ApsXs - ApiXi = Yp \qquad \text{----(vi)}$$

and

$$-AisXs + (I-Aii)Xi = Yi$$

$$G_3X_3 = 0$$

The equations forming $G_3X_3 = 0$ represent network balances and will have to be derived from the RES.

3.3 Data Requirements: The inputs to the I/O Model require an Input/Output table for the non-energy sectors of the economy (preferably that prepared by the planning body of the country), a complete picture of the energy flows in the economy in the form of the RES with relevant efficiencies and end-use demand patterns.

The LP model needs, in addition to the data of the I-O model, capital costs of various utilities, prices, import/export figures, stock changes, investment figures etc.

3.4 Results from the Model: The results would be in the form of gross outputs vector from the I/O model, optimal solutions from the LP and a set of shadow prices, also from the LP. The latter can be used as follows :

- Comparison of the magnitudes of $\lambda_D$ shows where conservation will be most cost-effective.
- Comparison of $\lambda_D$ with unit cost of conservation measure $C_D$. Conservation investments are justified where $\lambda_D > C_D$.
- $\lambda_S$ represents value of additional domestic energy sources to the energy system.
- Comparison of $\lambda_D$ and $\lambda_S$ indicates whether priority should be given to conservation investments or supply enhancements.

where,

$\lambda_D$: the shadow prices associated with the demand constraints

$\lambda_S$: the shadow prices associated with the supply constraints

A typical output for the LP Model is given in Table 3.7 in Appendix 3.1.

## 3.5 PROGRAM OVERVIEW :

### 3.5.1 I/O MODEL: I/O Model execution begins by typing

IOMODEL<R>

Then the package asks you to enter data filename. Please note that no file extension is allowed.

```
==> Enter data file Name?[Max 8 chars] ? XXXXXXXX<R>
```

You will be shown the following screen from where choice of an option can be made by entering its serial number and <R>:

```
¶                                                         ¶
                  [[ INPUT-OUTPUT MODEL ]]
1. Data  Entry/Edit for the Transaction Matrix (T) and
   Demand Vector (Y)

2. Compute Coefficient Matrix (A)

3.·Compute Inverted Matrix (B) [ B=INV(I-A) ]

4. Compute Output Vector (X)

5. Print a Matrix (T/A/B) or a Vector (Y/X)

6. Quit back to system

                  Select (1,2,3,4,5,6) ? 1<R>
¶                                                         ¶
```

Options in the I/O model screen are explained below :

1. Data Entry/Edit for the Transaction(T) Matrix and Demand(Y) Vector : Select this option to start or restart data entry, to add or delete a sector from the model, or to edit data. This is your data entry pack. More details are given later.

2. Compute Coefficient Matrix(A) : Select this option to compute the coefficient matrix (A) from the transaction matrix (T) for which the data is entered using Option 1.
3. Compute Inverted Matrix (B) [ B=INV(I-A) ] : Select this option to compute matrix(B). Coefficient matrix (A) which is created by option 2 is subtracted from the identity matrix (I) before inversion.
4. Compute Output Vector (X) : Select this option to compute gross output vector (X). B matrix computed using option 3 is multiplied by the demand vector (Y)

for which the data is entered through option 1.

5. **Print a matrix (T/A/B) or a vector (Y/X) :** Select this option to print any of the matrices T,A and B or any of the vectors Y and X.

6. **Quit back to system :** Select this option to go back to the system.

Data entry using option 1 is described in more detail here and use this section while entering the data. After selecting the Data Entry/Edit option you will be shown the following screen of display :

```
¶                                                      ¶
     [ Data Entry/Edit for T Matrix and Y Vector ]

1. Start/Restart Data Entry
2. Add a sector
3. Delete a sector
4. Display a sector row or column or Y vector
5. Edit a sector row or column or Y vector
6. Quit the menu
                   Select (1,2,3,4,5,6) ? 1<R>
¶                                                      ¶
```

Select one of these options by typing its serial number and <R>. The details of the various options are as follows:

[illegible] **Start/Restart Data Entry :** Select this option if you want to start/restart data entry. The following question appears on the screen after selecting this option:

```
==>Are you restarting the data entry
==>after a break (Y/N) ? X<R>
```

**N<R> Option :** Type N<R> if you are starting the data entry for the data file for the first time. A typical dialogue for the data entry consists of :

```
==> No. of Sectors ? 120<R>
```

In the next screen you can enter the different sector names.

```
¶                                                        ¶
Data Entry for T Matrix              No. of Sectors:120
Enter Sector names (max 40 chars):

     S.NO.                                Sector Name
       1                                  XXX...<R>

                               o
                               o
                               o
¶                                                        ¶
```

After finishing the sector name entry the following message appears on the screen :

```
¶                                                        ¶
                    Sector name Entry OVER!

                        Saving the data

                            WAIT !

                         Press any Key
¶                                                        ¶
```

Now you can start the data entry row wise for T matrix. The column number and the sector name are displayed in the first and second column of the display and you can enter data corresponding to them in the third column.

```
¶                                                                  ¶
Data Entry for T Matrix              No. of Sectors : 120
Row No : 1                          Sector : <sector name>

Col. No.             Sector        .     Enter Value here
   1                 XXX...                  XXX...
                                o
                                o
                                o
¶                                                                  ¶
```

In one screen it is possible to enter 20 data items. After entering the last data item the above screen will appear for further data entry. After finishing the data entry for the first row of the T matrix, the following messages appear on the screen.

```
¶                                                                  ¶
                         Data Entry OVER!

                               for

    Row No. 1                      Sector : <sector name>

                          Saving the data

                              WAIT !

                          Press any Key
¶                                                                  ¶
```

In the same way data entry is done for all the rows of the T matrix and finally for the Y vector.

Y<R> Option : Suppose you are restarting the data entry after a break (either voluntary or due to a power failure), type Y<R> for the first question you were asked after selecting option 1 in data entry screen. The following message tells you about the current status of the data entry.

```
==> Data saved upto Row No.: 50
==> Press any key to
==> Restart data entry from Row No. 51
```

The data entry is done as explained earlier.

2. **Add a sector** : Select this option to add a sector to the model. The following few lines of dialogue explains how an additional sector is registered in the model.

```
==> Add a sector to the Model :
==> Sector No. : 121
==> Type the Sector Name (Max 40 chars) ?  XXX...<R>
```

After registering the additional sector in the model you can enter the data for the additional row and column created for the new sector in the T matrix.

The data entry for the row is done as explained earlier. In a similar way data entry for the additional column is also done and it proceeds as follows:

```
_______________________________________________________________
¶                                                             ¶
Data Entry for T Matrix            No. of Sectors : 121
Column : 121                       Sector : <sector name>

Row No.              Sector             Enter Value here
  1                  <sector name>         XXX...<R>

                               o
                               o
                               o
¶___   ______________________________________________________¶
```

The data entry is done for each row as it was done for each column in earlier cases.

After the data is entered for the additional row and column created in the T matrix, enter data for the element corresponding to the added sector in the Y vector. It is done as :

```
¶                                                                ¶
    Data Entry for Y Vector      No. of Sectors : 121
    S.No. 121                    Sector : <sector name>
                        Enter Value here
                          XXX...<R>
¶                                                                ¶
```

3. Delete a sector : Select this option delete a sector from the model. The following dialogue explains how it is done.

```
==> Delete a Sector from the Model :
==> Type the Sector No. ? 100<R>
==> Sector to be deleted : <sector name>
==> OK to delete (Y/N) ? Y<R>
==> 100 <sector name> deleted from the Model
==> Press any Key
```

4. Display a Sector row or column or Y Vector : Select this option to display any row or column in the T matrix or the Y vector. The screen display and dialogue, during this operation is given below.

```
==> Display a Row/a Column/Y Vector:
==> Select (R,C,Y) ? X<R>
```

Type Y<R> to get the display of Y vector and type C<R> or R<R> to display a column or a row in the T matrix respectively.

```
==> Enter Row No. ? X<R>
```

The above message appears if R option is selected. When

C option is selected, a column number will be asked. The display shows 20 data items at a time with row and column numbers, and sector names. A typical display will appear as:

```
¶                                                              ¶
   Row No. 1                        Sector : <sector name>

  Col. No.              Sector                Value
     1               <sector name>             999...

     2               <sector name>             999...

                             o
                             o
                             o
                  WAITING! Q(uit)/C(ontinue)
¶                                                              ¶
```

The Q option in the above screen will take you to Input Output screen and the C option will continue the data display.

5. Edit a Sector row or column or Y Vector : Select this option if you want to edit data either in T matrix or in Y vector.

The dialogue to do this operation is given below :

==> To Edit a row/column/Y vector

==> Select (R,C,Y) ? X<R>

The R option selects a row, the C option selects a column and the Y option selects Y vector for editing. Supposing R option is selected the message on screen will be:

==> Enter Row No. to be edited ? XXX<R>

The following screen of dialogue explains how existing value is substituted by a new value.

```
¶                                                        ¶
Editing T Matrix

Row No. 1                               <sector name>

              Enter the Col. No. ? 10<R>

Col.No.             Sector              Current Value
  10            <sector name>              XXX...

             Enter new value ...? XXX...<R>
¶                                                        ¶
```

Editing the data for the Y vector or a column in the T matrix is also done in a similar manner.

6. Quit the menu : Select this option to quit the data entry/edit screen and to go to the INPUT-OUTPUT MODEL Screen.

The typical steps to execute the Input Output Model are:

1. Enter data for the T matrix and Y vector.
2. Compute A matrix.
3. Compute B matrix.
4. Compute X vector and print the output.
5. You can edit T matrix at any stage after step 1. After editing go to step 2.
6. To calculate the X vector for changed Y vector go to step 4 after editing.

3.5.2 Linear Programming Model: The LP model described earlier is executed on LP83 package developed by Sunset Software.

The Linear Programming software LP83 is constructed such that it can access a Lotus spreadsheet directly - this minimises the data entry problem. The recommended spreadsheet layout is illustrated below :

If the problem is given as

Maximise

10X + 20Y + 30Z

```
Bounds : X >= 2
         Y <= 10
         3 <= Z >= 15
```

Constraints :

```
ABC : 1X + 2Y + 3Z <= 100
DEF : 4X + 5Y + 6Z <= 200
GHI : 7X      + 9Z <= 300
```

The spreadsheet would look as

```
     A    B    C    D    E    F    G    H    I
 1.
 2.   Lotus Spreadsheet example
 3.
 4.                 X    Y    Z
 5.                10   20   30
 6.
 7.                 2         3
 8.                     10   15
 9.
10.            ABC 1    2    3    <=   100
11.            DEF 4    5    6    <=   200      <=
12.            GHI 7         9    <=   300
```

In this way the format of the Lotus file is similar to the LP83 equation style format. The lotus file has to define a number of ranges and the LP83 system looks for these specific range names defining the title, variables, pricing coefficients etc. The range names, then definitions, cell locations and comments for this example are listed in the table below :

| Range Name | Definition | Cell Locations | Comment |
|---|---|---|---|
| 83 TITLE | Problem title | $A_2$---$A_2$ | Not required |
| 83 VARIABLE | Variable names | $D_4$---$F_4$ | Required |
| 83 COST | Pricing coefficients | $D_5$---$F_5$ | Required |
| 83 LOWER | Variables lower bounds | $D_7$---$F_7$ | Not required |
| 83 UPPER | Variables upper bounds | $D_8$---$F_8$ | Not required |
| 83 CONTRAINTS | Technological coefficients | $C_{10}$--$H_{12}$ | Required |
| 83 VA | Variables activity at solution | $D_3$---$F_3$ | Not required |
| 83 CA | Constraints activity at solution | $I_{10}$--$I_{12}$ | Not required |
| 83 VR | Variables reduced cost | $D_2$---$F_2$ | Not required |
| 83 CR | Constraints reduced cost | $J_{10}$--$J_{12}$ | Not required |

A couple of points to remember are:

- the constraints section can and must have three more columns than the listed variables to account for the constraint name, equality/inequality sign and value of the constraint.
- the objective section must precede the constraints section
- a variable name can only be used once and all variables must be named
- the objective to minimise or maximise the problem is stated on the LP83 command line.

To solve the above problem the lotus spreadsheet as defined should be created and saved with all the appropriate range names and the LP83 run as

```
LP83 TEST.WKS MAXIMIZE YES
```

where TEST.WKS is the hypothetical file name given to the above problem. The command line has 'minimise' as its default objective function. If the above problem had been one of minimisation all one would have to say is

```
LP83 TEST.WKS.
```

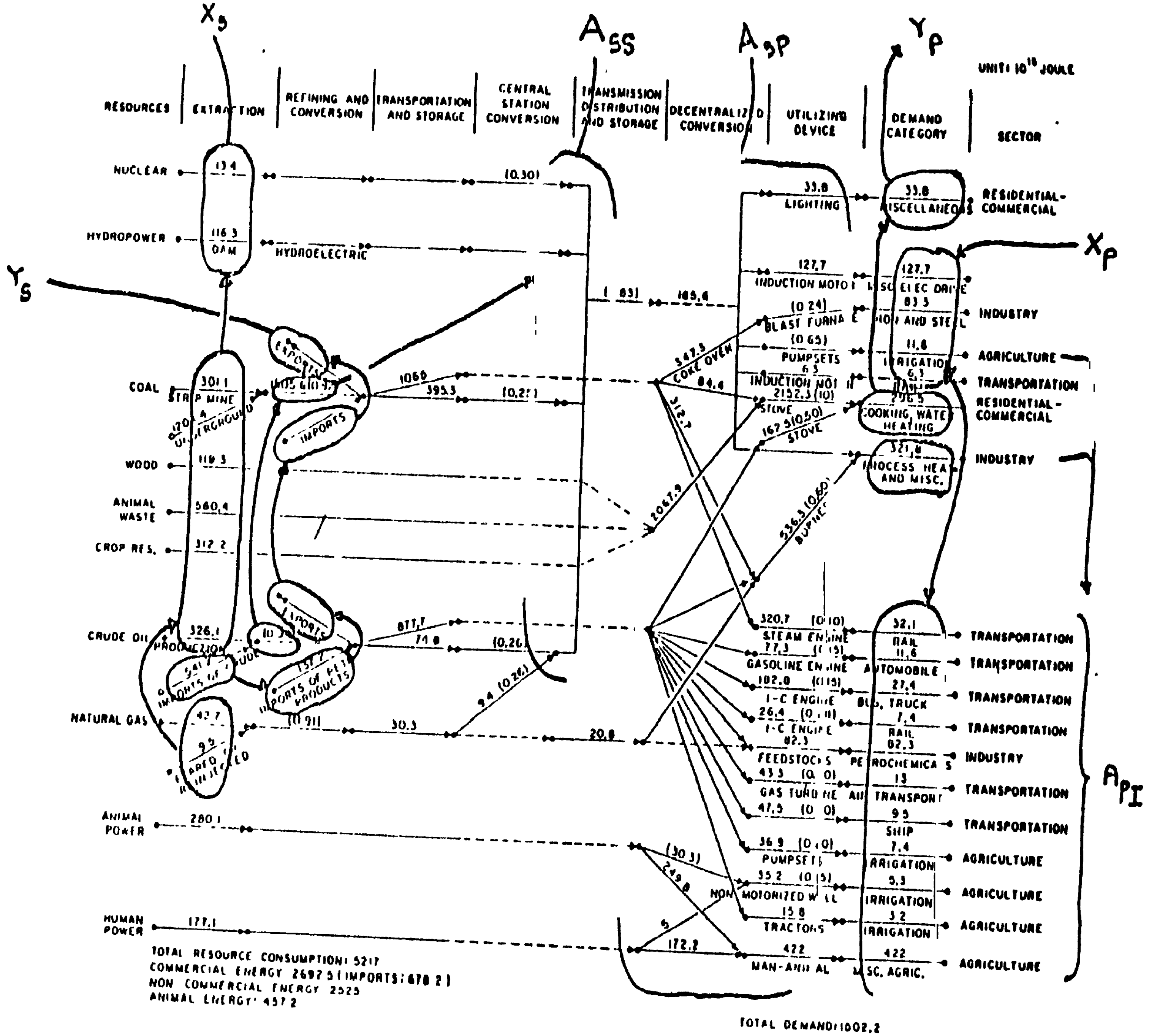


Figure 3.1 General Relationships between the I/O and the RES.

# 4. ELASTICITY ESTIMATION MODEL

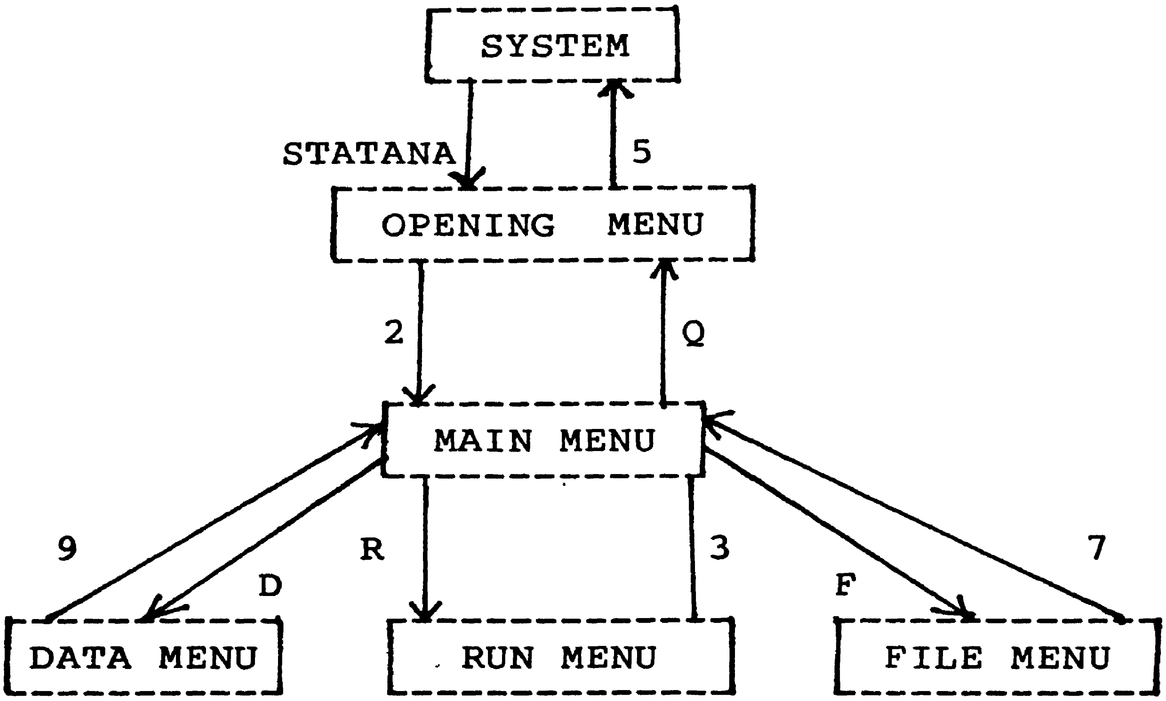
4.1 **Introduction:** This package can be used to estimate energy elasticity by carrying out regression analysis for a maximum of 15 variables and 100 data points. The regression equation can be either in the linear, log-linear or log-log forms. Along with the regression equation, the program output lists the coefficient of determination, t(test) values, DW statistics, F ratio, correlation matrix etc. This package can also be used to carry out simple statistical analysis for a maximum of 15 variables at a time. The output consists of mean and standard deviation for each variable and a linear correlation matrix of all the variables. In the log-log form, elasticities are obtained directly in the form of coefficients of the independent variables.

4.2 Program overview: This is a menu driven interactive package consisting of five different menus, in a hieararchical structure. Corresponding to an input data file, a job is registered on the disk. Every job is identified by an unique JOBCODE and a JOBNAME. A JOBCODE can have three alphanumeric characters and the JOBNAME can have fifty characters. Table 4.1 lists the functions performed by different menus and Figure 4.1 shows the pathways among the menus. Table 4.1 along with Figure 4.1 provides a summary of the program organisation and can be used as a quick reference guide.

Table 4.1 Menus and their Functions

| Menu | Functions |
|---|---|
| 1. Opening Menu | - Job file related operations like create, select or delete a job Obtain directory of jobs. |
| 2. Main Menu | - To select one of the following menus:<br>. Data Menu<br>. Run Menu<br>. File Menu |
| 3. Data Menu | - To perform operations (Enter, Edit, Display and Print) on variables and data points in the input data file. |
| 4. Run Menu | - To carry out regression and statistical analysis. |
| 5. File Menu | - To operate (Rename, Print, Display, Delete) on the files in the selected job. |

Figure 4.1: Pathways among Menus



Note: The options to be selected to choose a path are indicated on the arrows.

4.2.1 **Initialisation of the Package:** Follow the steps given below to execute this package.

a. Boot the system. Those who have a working copy on the hard disk proceed to step (c).

b. Load the working copy of the statistical package in A drive.

c. Type STATANA<R>

This will lead you to the Opening Menu of this module.

4.2.2 Opening Menu: One enters into this menu after beginning the execution of the program. Its display on screen appears as:

```
¶
                    [[    STATISTICAL ANALYSIS     ]]
-------
¶  O  ¶----->    1.  [ LIST the Directory of Jobs on the Disk ]
¶  P  ¶
¶  E  ¶----->    2.  [ SELECT a Job]
¶  N  ¶
¶  I  ¶----->    3.  [ CREATE a New Job ]
¶  N  ¶
¶  G  ¶----->    4.  [ DESTROY a Job   ]
¶     ¶
¶  M  ¶----->    5.  [ QUIT back to System   ]
¶  E  ¶
¶  N  ¶
¶  U  ¶           SELECT    (1-5)   ? X<R>
-------
¶
```

Now you can choose one of the options by typing its serial number and <R>.

The meanings of the options are as follows:

1. **List the Directory of Jobs on the disk:** Displays all the jobs on the disk with their serial number, JOBCODE and JOBNAME. If the directory is not accommodated in a

single screen, the rest wll be shown in the subsequent screens after pressing any key.

2. **Select a job:** When you select this option, program will display existing job codes and their serial numbers. If your job is already registered in an earlier session using option 3, you can select your job for further processing by typing its serial number and <R>. After confirmation about the job you have selected you will be shown the MAIN MENU.

3. **Create a new job:** Using this option you can register a new job and the dialogue proceeds as follows:

```
==> Type Job Code ?  TER<R>
==> Type Job Name ?  Test Job for Statistical Package <R>
```

After registering your job, the following question appears

```
==> Data Entry (Y/N) ? X<R>
```

If you want to enter input data type Y<R> otherwise N<R>. Typing Y<R> would take you to enter data option in the data menu. Typing N<R> will keep you in the opening menu.

4. **Destroy a Job:** Use this option to destroy a job: The conversation proceeds as follows:

```
==>      To destroy a Job
==>      Type its serial number     2<R>
==>      JOB CODE: <job code>
==>      JOB NAME: <job name>
==>      OK to Destroy (Y/N)  ?  Y<R>
==>      All file(s) in the Job are Deleted
==>      JOB is DESTROYED
```

This operation results in deleting all the files related to the job and the job registration is also removed. The job numbers get re-allocated once a job registration is cancelled.

5. Quit back to the System: Use this option to end the session and get back to system.

4.2.3 Main Menu Options: Once you select the job using option 2 in the opening menu the MAIN MENU appears on the screen as follows:

```
 ______________________________________________________________________
¶                                                                      ¶
                        [[ STATISTICAL ANALYSIS ]]

                             -----------------------------------------
--------        --------   ¶ [ Enter ]    [ Add a Variable ]         ¶
¶      ¶        ¶ DATA ¶   ¶ [ Edit  ]    [ Add a Data Point ]       ¶
¶  M   ¶  ----->¶ MENU ¶--¶ [ Display ] [ Delete a Variable ]       ¶
¶  A   ¶        --------   ¶ [ Print ]    [ Delete a Data Point ]¶
¶  I   ¶                     -----------------------------------------
¶  N   ¶        --------   ------------------------------------------
¶      ¶  ----->¶ RUN  ¶--¶ [ Multiple Linear Regression :           ¶
¶  M   ¶        ¶ MENU ¶   ¶ i Linear   ii Log-Linear iii Log-Log ¶
¶  E   ¶        --------   ¶ [ Simple Statistical Analysis ]        ¶
¶  N   ¶                     ------------------------------------------
¶  U   ¶        --------   ----------------------------------
¶      ¶  ----->¶ FILE ¶--¶ [ Directory ]    [ Display ]      ¶
--------        ¶ MENU ¶   ¶ [ Rename ]       [ Print ]        ¶
   ¶            --------   ¶ [ Delete ]       [ Dir Job ]      ¶
   ¶                         ----------------------------------
 --------
 ¶ QUIT ¶-----------------[ Goes back to Opening menu ]
 --------
                                                    JOB CODE : TER
      SELECT THE SUBMENU (D/R/F/Q)  ?
¶______________________________________________________________________¶
```

Now you have to choose one of the three sub-menus or the QUIT option as per your requirements by typing the first letter of the option and <R>. For your reference, the JOB CODE of the selected job is displayed at the bottom right corner.

Functions of each of the options in main menu is briefly described below:

1. **Data Menu:** Select this menu if you want to enter fresh data for the job or edit existing data. You can delete a variable, add a variable, delete a data point, add a data point or edit individual data values in the existing data file. You can also get the display and the print out in a proper format using the options in the data menu.

2. **Run Menu:** Select this menu to run multiple regression analysis for all or some variables and to perform simple statistical analysis for all variables in the data file.

3. **File Menu:** Select this option if you have to perform file operations. Using this option in the file menu, you can rename a file, delete a file, display the contents of a file or print out the contents of a file. Also there are options to display the directory of files on the disk and the directory of files in the job.

4. **Quit:** This option will take you to opening menu.

### 4.2.4 Data Menu Options:

Once you select data menu option in the main menu, the following display will appear on the screen:

```
¶                                                                         ¶
                         [ [ STATISTICAL ANALYSIS ] ]
-------
¶     ¶
¶     ¶----> 1. [ ENTER data for a new Job ]
¶     ¶
¶  D  ¶----> 2. [ ADD a variable to the existing Data file ]
¶  A  ¶
¶  T  ¶----> 3. [ ADD a Data point to the existing Data file ]
¶  A  ¶
¶     ¶----> 4. [ DELETE a Variable from the existing Data file ]
¶     ¶
¶  M  ¶----> 5. [ DELETE a Data point from the existing Data file]
¶  E  ¶
¶  N  ¶----> 6. [ EDIT data ]
¶  U  ¶
¶     ¶----> 7. [ DISPLAY data ]
¶     ¶
¶     ¶----> 8. [ PRINT data ]
¶     ¶
¶     ¶----> 9  [ QUIT back to Main Menu ]
-------

                                                         JOB CODE : TER
             SELECT (1-9) ? X<R>
¶________________________________________________________________________¶
```

Different options in data menu are described below:

1. Enter data for a new job: Variable names, their units, data point identifications and data are entered here. Data entry proceeds typically as:

```
==>     No of Variables [ Max 15 ] ? 3<R>

==>     No of Data Points [ Max 100 ] ? 12<R>
```

The variable name and the units are entered as:

```
==>                           Variable 1

==>     Name [ Max 30 Chars ] ? GDP<R>

==>     Unit [ Max 15 Chars ]
        ( <R> for No Unit ) ? Rs. <R>
```

After entering all variable names and units, following message is displayed.

```
==> Inputs  for variable names and units over.
==> Press <R> to continue.
```

Now, entry for data point identification is carried out as follows:

```
==> Data Point No. 1
==> Data Point Identification [ Max 7 chars ] ? 1980-81<R>
```

Data point identification is like a marker and can be a year for time-series data, place for cross sectional data, crop name for agricultural data etc. Now the data is entered for each variable as follows:

```
¶                                                           ¶
JOB CODE: TER          [ 3 VARIABLES ] [ 12 DATA POINTS ]

                                 Variable No. - 1
                                 Name : Variable 1
                                 Unit : None

Data point No. - 2
Identification : 1971-72

Enter Value here ---> ? 0.52<R>

                                o
                                o
                                o
¶                                                           ¶
```

This will take you back to data menu and you can select any of the nine options given there.

2. Add a Variable to the existing Data file: This option is used if a new variable is to be added to the existing data file. Dialogue to enter variable name, unit and its data proceeds as described in enter data option.

3. **Add a Data point to the existing Data file:** You can add a data point to the existing set of variables in the data file using this option. After entering data point identification, data for all variables can be entered.
4. **Delete a Variable from the existing Data file:** When you select this option a display of all variables will appear on the screen.

```
¶                                                            ¶

  JOB CODE : TER   [ 4 - VARIABLES ] [ 13 DATA POINTS ]

  No. Variable Name                        Variable Units
  1.  Variable 1                           None
  2.  Variable 2                           '00s
  3.  Variable 3                           None
  4.  Variable 4                           '00s
 Variable Details Displayed !

 DELETE A VARIABLE !

              Type the Sl. No. ? 4<R>

 VARIABLE DELETED !

 Press  <R> to continue.
¶                                                            ¶
```

A typical display and conversation is shown above. Deleting a variable results in deletion of all data entries for that variable.

5. **Delete a Data point from the existing Data file:** This option is to be used when you need to delete a data entry for all variables corresponding to a particular data point. A typical display during execution of this

option is shown below:

```
¶                                                                    ¶
 JOB CODE : TER          [ 3 - VARIABLES ] [ 13 - DATA POINTS ]

 1. 1970-71   2. 1971-72   3. 1972-73   4. 1973-74   5. 1974-75
 6. 1975-76   7. 1976-77   8. 1977-78   9. 1978-79  10. 1979-80
11. 1980-81  12. 1981-82  13. 1982-83
     Data Point Details Displayed

     DELETE A DATA POINT !

               Type the Sl. No. ---> ? 13<R>

     DATA POINT DELETED !

     Press <R> to continue
¶                                                                    ¶
```

6. Edit data: This option is used when you want to modify data entries selectively. To help you in editing data you will be shown details of data point identifications as below and you can select the Sl. No. of the data point.

```
¶

 JOB CODE : TER          [ 3 - VARIABLES ] [ 12 - DATA POINTS ]

 1. 1970-71   2. 1971-72   3. 1972-73   4. 1973-74   5. 1974-75
 6. 1975-76   7. 1976-77   8. 1977-78   9. 1978-79  10. 1979-80
11. 1980-81  12. 1981-82
          Data Point Details Displayed

          Edit Data !

                    Enter Data Point Sl. No. ---> ? 3<R>
¶                                                                    ¶
```

Having selected the Serial Number for Data Point, you will be shown the list of variables. Once the variable is selected by its Serial number, the current value for that variable will be displayed. You can then modify it. A typical display after completing the operation will be as below:

```
¶                                                                ¶
  JOB CODE : TER    [ 3 - VARIABLES ] [ 12 DATA POINTS ]

  No. Variable Name                         Variable Units
  1.  Variable 1                            None
  2.  Variable 2                            '00s
  3.  Variable 3                            None
       Variable Details Displayed !

       Editing Data Point No. - 3 (1972-73)

             Enter Variable Sl. No. ---> ? 2<R>

   Current Value = .1     New Value = ? .123<R>
¶                                                                ¶
```

7. Display data : This option can be used to display the data file of a job. A typical display is given below for illustrative purpose:

```
¶                                                                      ¶
                               DATA DISPLAY

No. Variable Name                          Variable Units
1.  Variable 1                             None
2.  Variable 2                             '00s
3.  Variable 3                             None
      Variable Details Displayed !

 1. 1970-71    2. 1971-72    3. 1972-73    4. 1973-74     5. 1974-75
 6. 1975-76    7. 1976-77    8. 1977-78    9. 1978-79    10. 1979-80
11. 1980-81   12. 1981-82
      Data Point Details Displayed

     VARIABLE -1    VARIABLE-2    VARIABLE-3    Data Pt. Id.
      .504            .108          .52            1970-71
      .52             .117          .56            1971-72
      .56             .123          .589           1972-73
      .589            .128          .629           1973-74
      .629            .137          .685           1974-75
      .658            .157          .75            1975-76
      .75             .178          .79            1976-77
      .79             .2            .864           1977-78
      .864            .21           .93            1978-79
      .93             .22           .977           1979-80
      .977            .234          1.056          1980-81
      1.056           .255          1.155          1981-82

     Data Display Over !
     Press <R>  to continue
¶
```

8. **Print data :** Using this option print the data file of the selected job. This option can be used immediately after entering data to obtain a printout for verification. After printing is complete, you can select any of the options from data menu.
9. **Quit back to Main Menu :** Goes back to main menu.

4.2.5 Run Menu Options: In the main menu, you select the run menu by typing R<R> if you want to run either the multiple regression analysis or the simple statistical analysis. You will now be shown the following screen:

```
¶                    [[  STATISTICAL ANALYSIS  ]]                    ¶
-------
¶     ¶
¶     ¶
¶  R  ¶-----> 1.  [ EXECUTE Multiple Regression :
¶  U  ¶                 i)  Linear
¶  N  ¶                ii)  Log - Linear
¶     ¶               iii)  Log - Log ]
¶     ¶
¶  M  ¶-----> 2.  [ EXECUTE Simple Statistical Analysis ]
¶  E  ¶
¶  N  ¶
¶  U  ¶-----> 3. [ QUIT back to Main Menu ]
-------
                                                  JOB CODE : TES
                  SELECT (1-3) ? 2<R>
¶                                                                    ¶
```

Select one of the options by typing its serial number and <R> . Details of operation in all opinions in Run menu are given below.

1. Execute Multiple Regression Analysis: Select this option if you want to carry out regression analysis on some or all of the variables in the job. The equations can be either in linear, log-linear or log-log format.

   The selection of independent, dependent variables and data point range is done as shown below. In this process you can select variables from the set of variables in the data file and assign them to dependent and independent variables one by one. Also you define the data point range for which the regression analysis to be carried out. To help you in selecting, information on data file is displayed in sufficient detail. Conversation between the package and the user proceeds as follows:

==> No. of Independent Variables ? 2<R>

Then the display of data point identification will appear from where you can select the data point range.

---

```
¶                                                                  ¶

 JOB CODE : TER          [ 3 - VARIABLES ] [ 12 - DATA POINTS ]

  1. 1970-71    2. 1971-72    3. 1972-73    4. 1973-74    5. 1974-75
  6. 1975-76    7. 1976-77    8. 1977-78    9. 1978-79   10. 1979-80
 11. 1980-81   12. 1981-82
           Data Point Details Displayed

    SELECT DATA POINT RANGE
    Sl. No. (FROM) ?  1<R>
    Sl. No.   (TO)  ? 12<R>

¶                                                                  ¶
```

---

After selecting the data point range the following message appears:

==> Selected Data Point Range Highlighted

==> Is this OK (Y/N) ? Y<R>

To help in the selection of dependent and independent variables, the variable names and other details will be displayed and a typical conversation will proceed as shown below. Dependent variable is selected first and then all independent variables are selected on.

```
¶                                                                  ¶
  JOB CODE : TER   [ 3 - VARIABLES ] [ 12 DATA POINTS ]

  No. Variable Name                           Variable Units
  1.  Variable 1                              None
  2.  Variable 2                              '00s
  3.  Variable 3                              None
       Variable Details Displayed !

   Select Dependent Variable (Y) ---> ? 3<R>
¶                                                                  ¶
```

The above screen explains how the dependent variable is selected. In the similar way all the independent variables are selected.

==> Select Independent Variable-1 (X1) ---> 2<R>

==> Select Independent Variable-2 (X2) ---> 1<R>

Note: Y      - Dependent Variable
      X1, X2 - Independent Variables

After the selection process is over, the final display will appear as shown below and you can check your selection.

```
¶                                                                  ¶
  JOB CODE : TER   [ 3 - VARIABLES ] [ 12 DATA POINTS ]

  No. Variable Name                 Variable Units
  1.  Variable 1                    None ---> X1
  2.  Variable 2                    '00s ---> X2
  3.  Variable 3                    None ---> Y
          Variable details displayed !

All the Variables Selected !
Is this OK (Y/N) ? Y<R>
¶                                                                  ¶
```

If you type N<R> then you will be taken to the beginning of variable selection. If you type Y<R> then you will be shown the following message.

```
==> Selection of Variables and
              Data point range
              is over !
==> Ready for execution !

==> Output File Name [MLR] (Max 8 Chars.) ? XXXXXXXX<R>
```

After entering the output file name you will be shown the following display:

```
¶                                                                    ¶
                        [ MULTIPLE REGRESSION ]

1.   Linear - Linear   Y = BO + B1*X1 + B2*X2 + ...

2.   Log - Linear      Log(Y) = BO + B1*X1 + B2*X2 + ...

3.   Log - Log         Log(Y) = BO + B1*Log(X1) + B2*Log(X2) + ...

where,

     Y : Dependent Variable
     X1, X2,... : Independent Variables
     BO : Constant coefficient
     B1, B2,... :  Other regression coefficients
     Select (1,2,3) 1<R>
¶                                                                    ¶
```

Here you can select one of the types of regression you want to carry out upon the selected data set by its serial number and <R>. The following message appears to inform you that it is doing the computation:

```
 ==> Carrying out regression analysis ....
```

Wait till you get the following prompt:

```
 ==> Execution over ...
```

```
==> Any more execution for the selected set (Y/N) ? Y<R>
```

Type N<R> to end this option and go back to run menu. If you type Y<R> you will be again shown the multiple regression screen to carry out one more regression of some other type for the same set of data. A sample output for a linear regression is given in Appendix 4.1.

2. Execute Simple Statistical Analysis: Select this option if you wish to carry out simple statistical analysis on all the variables in the job. You need to enter output file name and is shown below along with the messages.

```
¶               [ SIMPLE STATISTICAL ANALYSIS ]               ¶
Output filename [SSA] (max 8 chars) ? XXXXXXXX<R>
               Ready for execution !
Press <R> to start
               Carryingout simple statistical analysis....

¶              Execution over ...                             ¶
```

3. Quit back to Main Menu: Use this option to quit the run menu and go back to the main menu.

4.2.6 File Menu Options: Once you select the file menu option by typing F<R> in the main menu you will be shown the following screen of display:

```
¶                          [[  STATISTICAL  ANALYSIS  ]]
-------
¶     ¶ ---->     1.   [ DIRECTORY of files in the Job ]
¶  F  ¶
¶  I  ¶ ---->     2.   [ DIRECTORY of files on the Disk ]
¶  L  ¶
¶  E  ¶ ---->     3.   [ RENAME a file  ]
¶     ¶
¶     ¶ ---->     4.   [ DELETE a file ]
¶     ¶
¶  M  ¶ ---->     5.   [ DISPLAY the contents of a file ]
¶  E  ¶
¶  N  ¶ ---->     6.   [ PRINT the contents of a file ]
¶  U  ¶
¶     ¶ ---->     7.   [ QUIT back to Main Menu ]
¶     ¶
-------                                        JOB CODE: TER
                  SELECT (1-7) ? X<R>
¶
```

Now you can choose one of the options by typing its serial number and <R>. The meaning of options are as follows:

1. **Directory of files in the Job:** Select this option to display the list of files in the job. All the files related to a job will have the JOBCODE as their file name extensions. File names in MS-DOS/PC-DOS operating systems has the following format:

```
XXXXXXXX.XXX
NAME     EXTENSION
```

   When you are asked to type the filename for any file operation within the elasiticity estimation package type only the name. Note that extension is not to be typed.

2. **Directory of files on the Disk/floppy:** Select this option to display the list of files on the disk. This will display all the files on the disk irrespective of the job you have selected.

3. **Rename a file:** Select this option to rename any file in the job except the data file. The following lines illustrate the dialogue that takes place:

```
==>         Type the file name  ? XXXXXXXX<R>
==>         New name            ? YYYYYYYY<R>
```

4. **Delete a file :** Select this option to delete any file except the data file from the job and to erase it from the disk. (The data file will be erased only when you destroy the job from the disk)

The following text illustrates the dialogue that takes place:

```
==>     Delete a File !
==>     Type the file name ?  XXXXXXXX<R>
==>     OK to delete the file  [XXXXXXXX.XXX]  (Y/N) ? Y<R>
==>     XXXXXXXX.XXX deleted from the disk
```

5. Display the contents of a file: Use this option to display the contents of any file in the job except the data file. (DISPLAY Data option in the data menu displays the data file in a proper format). The display will consist of 20 lines per screen followed by:

```
==> WAITING ! Q(uit)  or C(ontinue) Q<R>
```

Type Q<R> to get back to filemenu. Type C<R> to continue display of file contents. (Pressing only <R> is equivalent to typing C<R>).

6. Print the contents of a file : Use this option to print the contents of any file in the job except the data file. (PRINT Data option in the data menu prints the data file in a suitable format)

The dialogue that takes place is as follows:

```
==>    PRINT a File!
==>    Type the file name  ? XXXXXXXX<R>
==>    Printer Ready ?
==>    Press <R> to start Printing <R>
```

Press <R> after setting the paper in the printer and it is ready to print. Push SEL button on the printer if the SEL indicator is not ON. When the print is completed the following message is displayed on the screen.

```
==>       End of file !  PRINT OVER
```

7. Quit back to Main Menu : Use this option to go back to the screen showing the main menu.

## 4.3 File Conventions and Hints:

### 4.3.1. File Conventions:

1. Data file: Each job has an unique data file. The name of the data file is:

   DATA.XXX where XXX represents jobcode

2. Output files: Unless otherwise you enter the output file name, the results are stored in files with default file names. For multiple regression analysis, the default result file name is:

   MLR.XXX where XXX represents Jobcode

   For simple statistical analysis, the default result file name is:

   SSA.XXX where XXX means as above.

   When you enter the file name of your choice you need to type only the first name (i.e., file name without extension) and it will assume the jobcode as the file extension.

3. Backup data file: Whenever you edit the data file using the options in the data menu a backup file is created and the latest edited version is stored in the

data file. The name of the data backup file is:

DATABAK.XXX

### 4.3.2 Hints:

1. If the data file gets corrupted due to system or power failure use the following system commands to rename the data backup file after deleting the data file. To delete the data file,

```
DEL DATA.XXX                    XXX : Job Code
```

and for renaming type,

```
REN DATABAK.XXX DATA.XXX
```

The databak file is created or updated whenever you do editing using the options in data menu. If the databak file is not created earlier then the data has to be entered once again.

2. Effect of pressing <R> alone while making a choice:

a) If it is a Y(es)/N(o) choice, N(o) will be selected.

b) If it is in a menu, menu will be redisplayed.

c) If it is in the Multiple Regression screen, display will be repeated

d) If it is a Q(uit)/C(ontinue) choice, C(ontinue) will be selected

3. Pressing <R> alone while entering values will be equivalent to entering a zero value.

4. In all other operations pressing <R> alone will take you to the previous step.

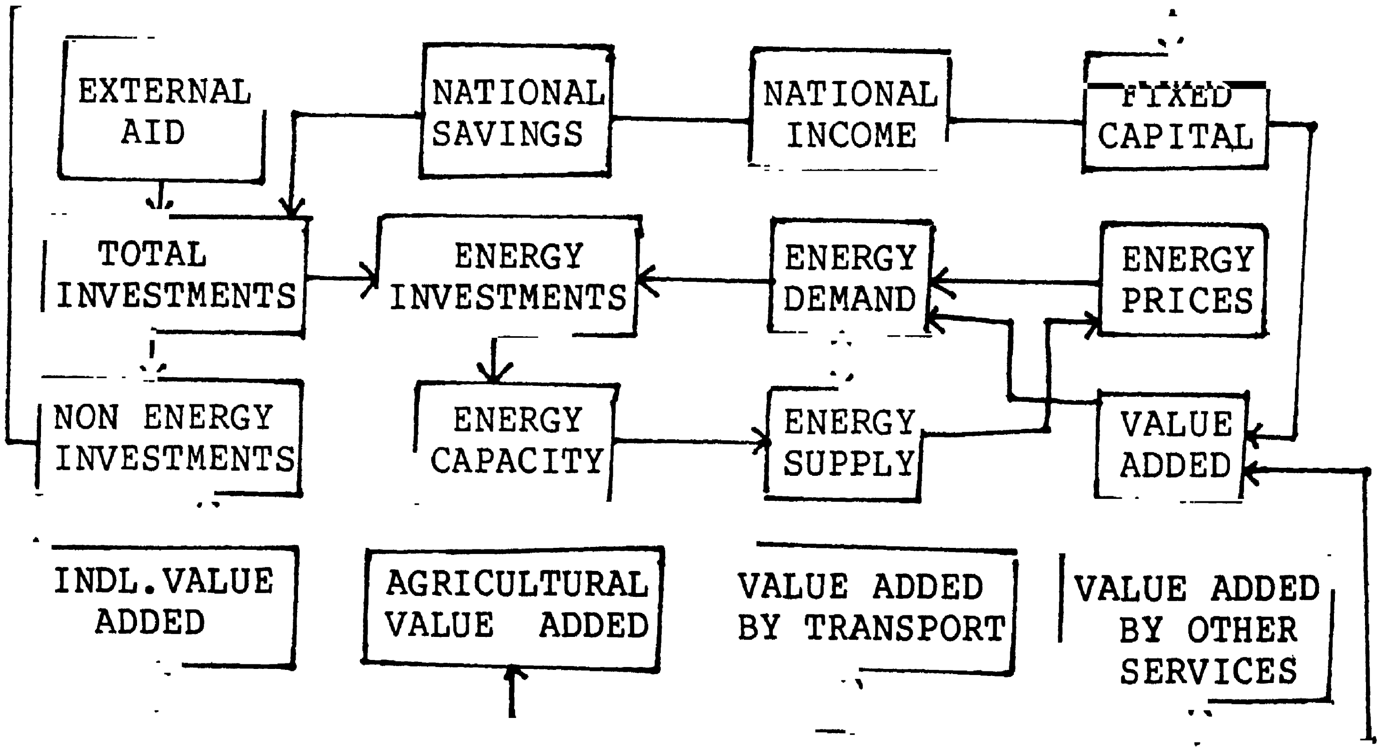
5. To abort the execution at any stage press <Ctrl> and <C> simultaneously. If it is done while entering or editing the data file the data will not be saved.

6. When many data corresponding to the particular variable or a particular data point are to be edited, instead of doing it through edit data option in the data menu we suggest a faster way of doing it. First delete that particular variable or data point from the data file and add the variable or data point again and enter the new values.

# 5. RESOURCE ALLOCATION MODEL

**5.1 Introduction** : This is a simulation package developed to study the interactions within the economy. These interactions are illustrated in the following flow diagram. Though highly aggregated, this flow diagram captures the main linkages within the Indian economy. The level of investment in both the energy and the non-energy sectors is seen to be affected by the level of savings in the economy and the availability of external aid. The double headed arrow between energy investments and non-energy investments indicates that there is an opportunity cost involved in terms of investment in any of these sectors to the other.

Flow Diagram



5.2 Model Description : An econometric approach has been adopted to model the various modules produced in the figure above. Thus, functional relationships between these macro-economic variables were first specified and linear regressions were run using time-series data for 12 years. The simplified functional relationships are reproduced below:

$Y = f(K, D)$

$B = f(Y)$

$I = f(A,B)$

$V = f(K)$

$EI_i = f(I,D_i)$

$D_{ij} = f(V_j,N,P_i)$

$C_{i,t} = f(EI_{i\ (t-1)}, C_{i(t-1)})$

$S_i = f(C_i,\ P_i,\ D_{i(t-1)})$

Where

Y = National Income

K = Fixed Capital

B = National Savings

A = External Aid

I = Total Investments

NEI = Non-Energy Investments

EI = Energy Investments

V = Value Added

D = Energy Demand
S = Energy Supply

C = Energy Capacity

P = Energy Prices

N = Population

i = Subscript for the Energy type

j = Subscript for sector

t = Subscript for time period.

Regressions were run on all the functional relationships with fairly good results. Some of the relationships exhibiting a high degree of multicollinearity were modified. The final set of equations for India were as follows :

(i) $Y = f(K,D)$
$= 84.61 + 0.3673K + 4.0825D \quad R^2 = .925$

(ii) $B = f(Y)$
$= -5737.2 + 34.941Y \quad R^2 = .915$

(iii) $I = f(A,B)$
$= -1915.3 + 0.087265A + 0.649435B \quad R^2 = .964$

(iv) $EC_{(t)} = f[EC_{(t-1)}, El.Inv_{(t)}]$
$= 6.9454 + 0.990715 EC +$
$0.029881 El.Inv. \quad R^2 = .991$

(v) $PPS = f(PI, RC)$
$= 9.1172 + 0.0197 PI + 0.3815 RC \quad R^2 = .882$

(vi) $ES = f(EC)$
$= 83.4336 + 3.4712 EC \quad R^2 = .991$

(vii) $CS = f[CI, CS_{(t-1)}]$
$= 40.76367 + 0.118763 CI +$
$0.462372 CS_{(t-1)} \quad R^2 = .996$

Where,

EC = Electricity Capacity

ES = Electricity Supply

CS = Coal Supply

CI = Coal Investments
PPS = Petroleum Product supply
PI = Petroleum Sector Investments
RC = Refinery Capacity

Direct relationships between some of the variables were assumed such as

i) Industrial Investment (II) $= f(\mathrm{NEI})$
$= 0.2\ \mathrm{NEI}$; and

ii) $$K_t = f(K_{t-1}, II_{t-1}) = 0.95K_{t-1} + II_{t-1}$$

It was further assumed that energy demand, external aid and petroleum refinery capacity are given exogenously.

The specified set of equations were run as a simultaneous equation problem for a period of five years.

Having determined the level of fixed capital from the previous year and given energy demand exogenously, the first variable to be determined was that of national income. This then became the independent variable for determining national savings which in turn along with the exogenously given external aid variable went to determine the level of total investments in the country.

Once the level of total investment was determined, we allocated it heuristically as energy and non-energy investments. To study the sensitivity of the economy to investment changes, we made three scenarios - the first proportioned total investments on the basis of current trends in the ratio of 82:18% between the non-energy and energy sectors, the second allocated 90% of total investments to the non-energy sector and the third 70% to the non-energy sector.

Within the energy sector it was assumed that 55% of investments went to the power sector, 30% to the petroleum sector and 15% to the coal industry. These shares were held constant over the three scenarios.

Having determined the levels of investments, the energy supply equations were run by each sub-sector. The resulting total energy supply position was then compared with the energy demand given exogenously to see the likely shortfall.

5.3 Data Requirements for Forecasting Purposes: The regression equations mentioned above are needed to run the model. These can be obtained from time series data for the specified variables using elasticity estimation model explained in Section-4 of this manual.

The forecasting period has to be specified (Max. 15 years). Data required during the forecasting period and its preceding year are listed below. Distribution of total investment in energy and non-energy sectors and their further distribution in oil and coal sectors and industrial sector respectively is also to be provided to the model exogenously. Annual depreciation rate is given by the user.

- **Regression equations needed:**

1. National income = f(Fixed capital, Energy demand)
2. National savings = f(National income)
3. Total investments = f(External aid, National savings)
4. Electricity capacity= f(Electricity capacity < prev. Yr>, Electricity investments)
5. Electricity supply = f(Electricity capacity)
6. Coal supply = f(Coal investment, Coal supply < previous year>)
7. Petroleum product supply = f(Petlm. investment, Refining capacity)

- Data needed for the previous year of the forecasting period:

1. Electricity capacity 2. Fixed capital 3. Coal supply

4. Industrial investments.

- Data needed for the years in the forecasting period :

1. Energy demand 2. External aid 3. Refinery capacity

- Investments distribution ratios needed:

1. Total investments => Energy : Non-energy investments
2. Energy investments => Petroleum : Electricity : Coal
3. Non-energy investments => Industrial investments

5.4 Program Execution: A typical user-computer interaction during execution of this program is given below. Type RESOURCE<R> to initiate this program. You will see the following display.

```
¶                                                               ¶
                    RESOURCE ALLOCATION PROGRAM

For Forecasting the following Parameters

1. National Income

2. Total Investments

3. Energy Supply

4. Energy Surplus / Deficit (given the Energy Demand)

Define Forecasting Period:

Forecasting   period  in   years  (Max 15  years) ... ? 15<R>

Period starting year
(Ex: Enter the financial
year 1980-81 as 1980)                         ...  ?  1980<R>
¶                                                              ¶
```

After defining the forecasting period, the next screen display will end with the following question.

```
==> Are you ready, say (Y/N) ? Y <R>
```

An N<R> response here will terminate the program. Y<R> response will take you to the following screen.

```
¶                                                              ¶
 Regression equation No.1

  Y = B0 + B1*X1 + B2*X2

      Y   : National income (in currency)
      X1  : Fixed capital   (in currency)
      X2  : Energy demand   (in MTOE)

Enter the values for :

                B0              B1              B2
                84.61<R>        0.3673<R>       4.0825<R>
¶                                                             ¶
¶                                                              ¶

Regression equation No.2

  Y = B0 + B1*X1

      Y  : National savings  (in currency)
      X1 : National income   (in currency)

 Enter the values for :

           B0              B1
           -5737.2<R>      34.941<R>
¶                                                              ¶
```

This process will continue till coefficients of all equations listed in Section 5.3 are entered. Then the program asks you for investment distribution ratios as :

```
¶                                                              ¶
 Investment distribution ratios No. 1

    Distribute :

           Total Investments
       for the following sectors

Enter the share for each sector (in %) :

          Energy                      Non-energy

          30<R>                        70<R>
¶                                                              ¶
```

The next screen will be :

```
¶                                                              ¶

Investment distribution ratios No. 2

    Distribute :

           Energy Investments
        for the following sectors
Enter the share for each sector (in %) :

        Petroleum        Electricity        Coal

        30<R>             55<R>             15<R>
¶
```

Similarly, non-energy investment share for industrial sector will be entered. To enter annual depreciation rate, following display will appear.

```
¶                                                                  ¶
Annual depreciation rate on

      Fixed capital

Fixed   capital   =   (Fixed capital < previous  year  >  *
                      Annual depreciation rate) + Industrial
                      investments < previous year >

Enter the value of

            Annual depreciation rate (in %)

                              5<R>
¶                                                                  ¶
```

Data needed for the previous year of the forecasting period is entered as follows :

```
¶                                                                  ¶
Data  needed  for the previous year of  the  forecasting
period.

Enter data for the year 1979

1. Fixed capital (in currency) .... ? XXX... <R>

2. Industrial investments (in currency) .... ? XXX... <R>

3. Electricity Capacity (in Mega Watts).... ?  XXX... <R>

4. Coal Supply (in MTOE) .... ? XXX... <R>
¶                                                                  ¶
```

Data for forecasting period is then entered as :

```
¶                                                                   ¶
Data needed for the forecasting period ( 1980 - 1994 )

Enter values for :

Sl No    Year    Energy demand   External aid       Refinery
                  (in  MTOE)   (in currency )  (in Million
                                                   tonnes)
 1      1980<R>    XXX<R>            XXX<R>          XXX<R>
¶                                                                   ¶
```

The program is executed at this stage and results are given in the format shown below. To transfer these results to the printer, press <PrtSc> along with < ⇧ > key

```
¶                                                                   ¶
RESULTS FOR THE FORECASTING PERIOD (1980 - 1994) :
                                    o
                                    o
                                    o

Sl   Year    National     Total      Energy   Energy    Energy
No           income    investments   demand   supply    surplus
            (in curr-  (in curren-    (in      (in       (in
             ency)      cy)          MTOE)    MTOE)     MTOE)


1    1980                             o
                                      o
                                      o
¶                                                                   ¶
```

When you exit the above screen, the following question appears on the screen.

```
                                                        ________¶
¶
Do you want the
                         FORECASTING

for any more set of
investment distribution ratios
                  Say  Y (es)  or  N (o)  ?
                                                        ________¶
¶
```

If you say Y<R>, you will need to supply only the new investment distribution ratios to obtain the forecasting results. Typing N<R> will end the program.

# 6. RURAL ENERGY MODEL

6.1 Introduction : Integrated energy planning at village level involves an understanding of existing indigenous resources, energy supply from outside and energy use patterns within the village. This knowledge of energy supply and demand in the village can be used to arrive at basic strategies for adjusting energy flows to meet changing needs - fuel switching, indigenous resource development, conservation, new and renewable supply options - into a comprehensive and "least cost" plan. The present model selects the most optimal mix of resources and technologies to meet the total energy demand in a village. It is developed in a static linear programming framework. The objective function of the model minimizes the energy supply cost of the system. This model becomes particularly relevant while making a village level energy plan.

6.2 Description of the Energy System : The village energy system is represented in Figure 6.1 by a network called 'Reference Energy System' (RES), in which the energy starting in a form of primary energy is flowing and is gradually transformed so as to yield the final energy. The final energy is transformed further down to useful energy so as to satisfy a given exogenous demand.

From the graphical representation of RES in Fig.6.1, two different subsystems can be identified as :

1) Supply Subsystem and
2) Utilization Subsystem.

A detailed information on these subsystems is provided below.

**6.2.1 Supply Subsystem :** The supply subsystem can be further categorised into :

1) Primary energy resources
2) Secondary energy forms

1. Primary Energy Resources :

They are classified in four categories :

a) Traditional energy resources : In this model three types of traditional energy sources, (wood, cowdung and crop residue) which are either gathered or produced in the village, are taken into consideration.

b) Commercial energy resource : These are the fossil fuels and electricity purchased from the grid.

c) Animate energy resources : These constitute the energy provided by the human labour and animals. This model accounts for animal energy only.

d) Renewable energy resources : These include solar and wind power. A calculation of the availability of these energy resources is made after measuring the solar intensity and the wind speed at the village itself.

In this model, the maximum quantity of primary energy resource that is available will have to be specified by the user exogenously..

### 2. Secondary Energy Forms :

Two types of energy forms viz. biogas and decentralised electricity are considered. These energy forms are produced using above mentioned primary fuels and are processed through the various conversion facilities (such as bio-gas plants, wood gasifiers and generator sets.)

The maximum amount of secondary energy form (bio-gas, electricity etc.) is calculated indigenously by the model. This is done by taking into account the capacity factor of the generating devices with resource availability as one of the major limiting factors.

Table 6.1 provides a listing of all energy resources and forms included in the model. More energy resources can easily be added to this list or eliminated as per requirement, by the user himself. The addition of a new resource would imply tracing out its path indicating its utilisation pattern in the RES network and just the reverse for elimination of a resource.

Table 6.1 : Energy Supply Subsystem

| Primary Energy Resource | | | | Secondary Energy Form |
|---|---|---|---|---|
| Traditional | Commercial | Animate | Renewable | |
| 1.Cow dung | 4.Charcoal | 9.Animal Power | 10.Wind<br>11.Solar | 1.Biogas<br>2.Decentralised Electricity |
| 2.Crop-residues | 5.Coal/coke<br>6.Kerosene | | | |
| 3.Firewood | 7.Electricity<br>8.Diesel | | | |

Table 6.2 lists the energy-generating devices considered in the model along with the corresponding primary energy source and secondary energy forms.

Table 6.2

| Energy-Source (Input) | Conversion Technology (Energy-generating devices) | Energy Form (Output) |
|---|---|---|
| 1. Cow dung | 5 cu.m. Bio-gas plant | Biogas |
| 2. Cow dung | 25 cu.m. Biogas plant | " |
| 3. Cow dung | 85 cu.m. Biogas plant | " |
| 4. Firewood gas | 5 hp. gasifier gen.set | Electricity |
| 5. Firewood gas | 15 hp. gasifier gen.set | " |
| 6. Firewood gas | 35 hp. gasifier gen.set | " |
| 7. Diesel | 5 KW diesel gen.set | " |
| 8. Diesel | 10 KW diesel gen.set | " |

### 6.2.2 Utilisation Sub-System :

#### 1. Household Sector

This sector includes all households in the village. The energy used by rural households is assumed to be mainly for

a) cooking
b) water heating and
c) lighting.

The energy requirement is measured in terms of useful energy i.e. primary energy contents multiplied by the efficiencies with which they are used.

## 2. Agriculture Sector :

The various agricultural activities that have been accounted in this model are :

a) pumping
b) threshing and winnowing
c) land-preparation

Pumping and land-preparation are the major commercial energy consuming agricultural activities. Threshing is generally done manually.

The calculation made for useful energy requirement for these activities are based on the measurements such as number of hours of operation of a particular device, (e.g. pumpsets, threshers etc.), its horse-power rating and its output in terms of volume of water drawn (for pumpsets), area prepared (for tractors) etc. Options considered for pumping are diesel, electric, wind and gasifier pumps. Various capacity-ranges (in terms of horse-power rating) have been considered. For land-preparation, tractors and bullock-driven ploughs are the two alternatives taken into account.

## 3. Transport Sector :

For the rural sector, the various modes of transportation that have been included in the model are:

a) tractors
b) animal driven carts.

The calculation for the useful energy requirement should be estimated on the actual useful work done in terms of a passenger kilometer or tonne kilometre, kilometre travelled multiplied by the energy input, by any mode of transport. For example, to cover one kilometre a tractor (seating capacity - 4 persons, cargo capacity - 150 tonnes) consumes 3 litres of diesel i.e. 4 passenger-km is equivalent to 3 lts = 2677.2 K.Cal = 31.09 KWH, i.e 1 passenger km is equivalent to 7.77 KWH. Thus, 7.77 KWH is the actual energy input coefficient for one unit of useful work (in this case passenger-km). In a similar way, coefficient for energy input for 1 tonne-km can be calculated.

**4. Village Industries Sector :** This would include food processing industries such as bakeries, flour mills, rice mills, poultry farms etc. This sector has not been included in the test-run for this model, as the test-data was obtained from a village in Haryana which did not own any small-scale industry.

The list of this utilisation subsystem can be easily extended/reduced as per requirement of the particular country. RES provides an excellent basis for this extension/reduction of not only the utilisation subsystem but of the energy system as a whole.

Table 6.3 provides a listing of the energy devices considered in the model and different tasks they are capable of performing.

Table 6.3

| Tasks/activities | Energy Source | End Use Device |
|---|---|---|
| 1. Cooking (medium temp. heating) | 1.cow-dung, Crop-residue | improved cook stove |
| | 2.firewood | improved firewood stove |
| | 3.kerosene | kerosene stove |
| | 4.Bio-gas | Bio-gas burner |
| | 5.solar | Solar cooker |
| | 6.soft coke/coal | Chullah |
| 2. Water heating (low temp.) | 1.electricity | immersion rod |
| | 2.solar | solar water heater (plus all of the cooking devices barring solar cookers) |
| 3. Lighting | 1.kerosene | lantern |
| | 2.electricity | bulb |
| | 3.bio-gas | mantle |
| 4. Stationary power (for water pumping) | 1.diesel | 5 hp diesel motor |
| | 2.diesel | 8 hp diesel motor |
| | 3.diesel | 10 hp diesel motor |
| | 4.electricity | 3 hp electric motor |
| | 5.electricity | 5 hp electric motor |
| | 6.electricity | 8 hp electric motor |
| | 7.wind | 5 hp wind motor |
| | 8.wind | 10 hp wind motor |
| | 9.wood | 5 hp gasifier motor |
| | 10.wood | 10 hp gasifier motor |
| | 11.wood | 25 hp gasifier motor |
| 5. Stationary power (for threshing and winnowing) | 1.Electricity | 5 hp drumi |
| | 2.Electricity | 15 hp thresher |
| | 3.Diesel | 15 hp thresher |
| 6. Mobile power (for land preparation and transportation) | 1.diesel | 35 hp. tractor |
| | 2.diesel | 51 hp. tractor |
| | 3.draft power | bullock cart/ plough |

6.3 Model Description : After an overview of the structure of the RES i.e. energy supply and demand sectors, it becomes easier to understand how the model matches the energy demand (given on the RHS of the RES) for various end-uses and the available energy resources (given on the LHS of the RES).

The model selects the best possible way of meeting the energy requirement for a particular end-use on the basis of the cost-economics. It picks up the least-expensive technology that can provide energy for a particular end-use and looks for an alternative way only when it comes across a limiting constraint associated with that technology. Some of the constraints can be in the form of :

i) maximum capacity available from this technology is not enough.

ii) there is a limitation on the availability of the energy resource that it (technology/device) makes use of.

iii) the limitation on the monetary resource available for the use of this particular technology.

### 6.3.1 Mathematical Formulation of the model

Minimise Annual Cost

$$Z = \sum_{i}\sum_{j} X(i,j)C(i,j) + \sum_{j1} Y(j1).F(j1) + \sum_{j2} Z(j2).F(j2)$$

$$j1 + j2 = j$$

where,

X(i,j) : Amount of energy supplied annually by an energy resource i to enduse j

C(i,j) : Variable cost of supplying one unit of output (in KWH) from energy resource i to the $j^{th}$ enduse

Y(j1) : Number of units of the $j1^{th}$ energy generating devices

F(j1) : Fixed cost (annual) of installing a $j1^{th}$ energy generating device

Z(j2) : Number of units of the $j2^{th}$ energy utilising device

F(j2) : Fixed cost (annual) of installing a $j2^{th}$ energy utilising device

Energy Constraints :

1. Supply constraints : These constraints ensure that the total use of any primary energy cannot exceed its availability.

$$\sum_{j} X\ (i,j) \leqslant X\ (i) \qquad \forall\ i$$

| | |
|---|---|
| amount of energy supplied annually by an energy resource i to end-use j. (in KWH) | maximum amount of $i^{th}$ primary energy resource available. (in KWH) |

2. Energy Demand Constraints : These constraints ensure that the total energy supplied by the energy system for any end-use equals or exceeds the demand of energy for that end-use.

$$\sum_{j2} Y\ (j2,k) \geqslant D\ (k) \qquad \forall\ k$$

| | |
|---|---|
| Output of the $j2^{th}$ energy utilising device for the $k^{th}$ end-use (in KWH) | Demand for energy for the $k^{th}$ end use (in KWH) |

3. Input-Output Balance Constraints:

1. For energy utilising devices

$$\sum_{i} X\ (i,j2)\ .\ E\ (i,j2) - \sum_{k} Y\ (j2,k) = 0 \qquad \forall\ j2$$

| | | |
|---|---|---|
| Amount of $i^{th}$ primary energy form supplied to the $j2^{th}$ energy utilising device. | Efficiency of the $j2^{th}$ device using $i^{th}$ energy resource | Output of the $j2^{th}$ energy utilising device, supplying energy to the $k^{th}$ end use |

### 2. For energy generating devices

$$\sum_{i} X\,(i,j1)\,.\;E\,(i,j1) \;-\; Y\,(j1,i1) = 0 \quad \forall j1$$

| $\sum_{i} X\,(i,j1)$ | $E\,(i,j1)$ | $Y\,(j1,i1)$ |
|---|---|---|
| Amount of ith primary energy form supplied to the j1th energy generating device | Eff. of the j1th device using ith energy form | Output of the j1th energy generating device generating i1th secondary energy form |

## 4. Capacity Constraints :

### 1. For energy utilising devices

These constraints ensure that the total energy supplied from an energy system j2, for the end use k does not exceed its total capacity.

$$\sum_{k} Y\,(j2,k) \;-\; Y\,(j2)\,.\;CAP\,(j2) \leq 0 \quad \forall j2$$

| $\sum_{k} Y\,(j2,k)$ | $Y\,(j2)$ | $CAP\,(j2)$ |
|---|---|---|
| Output of energy from the j2th energy utilising device to the kth end use. (in kWh). | No. of units of j2th energy utilising device (Nos.) | maximum annual capacity of the j2th device (in kWh) |

### 2. For energy generating devices

$$\sum_{j2} Y\,(j1,j2) + \sum_{i1} Y\,(j1,i1) \;-\; Y\,(j1)\,.\;CAP\,(j1) < 0 \quad \forall j1$$

| $\sum_{j2} Y\,(j1,j2)$ | $\sum_{i1} Y\,(j1,i1)$ | $Y\,(j1)$ | $CAP\,(j1)$ |
|---|---|---|---|
| Output of the j1th device supplying energy to the j2th device | Output of the j1th device generating i1th secondary energy form (in KWH) | No. of units of the j1th device (numbers) | Maximum capacity of the j1th device (in KWH) |

## 5. Non-Negativity Constraints:

$$X\,(i,j) \geq 0, \qquad Y\,(j,k) \geq 0$$

This constraint ensures that energy supplied by any source to any utilising/generating device and their output is non-negative.

$$Y\,(j1) \text{ and } Y\,(j2) \geq 0$$

This ensures that the number of any type of energy device is non-negative.

These non-negative constraints do not have to be specified, while executing the model with LP83.

**Legends and variable names**

$X(i,j)$ = input of energy sources i (primary and secondary) into the $j^{th}$ device (energy generating and utilising devices) (Unit : KWH)

$i$ = index of energy sources ($i = 1,2,\ldots.13$)

$j$ = index of the various devices ($i = 1,2,\ldots.39$)

also $j$ = $j_1 + j_2$

where, $j_1$ = index of energy generating devices ($j_1 = 1,2,\ldots.11$)

$j_2$ = index of energy utilising devices ($j_2 = 12,13,\ldots.39$)

$Y(j,k)$ = $Y(j_1, k) + Y(j_2, k)$

$Y(j_1,k)$ = Output of the ${j_1}^{th}$ energy generating device feeding into the $k^{th}$ energy utilising devices ($k=j_2=12,13,\ldots.39$) (Unit : KWH)

$Y(j_2,k)$ = Output of the ${j_2}^{th}$ energy utilising device feeding into the $k^{th}$ end-use ($k = 1,2,\ldots.7$) (Unit : KWH)

$Y_j$ = number of units of the $j^{th}$ device (Unit : numbers)

RM $\underline{i}$ = Constraints with this label corresponds to the maximum availability of the ith primary energy resource. Mathematically, these constraints can be written as

$$\sum_j X(i,j) \leqslant X_i \text{ (max. amount available for the } i^{th} \text{ resource)} \qquad \forall i$$

DD $\underline{k}$ ($k=1,2\cdots 7$) = Constraints with this label ensures that the minimum energy requirement for all the $k^{th}$ end uses is met. The mathematical description is

$$\sum_{j_2} Y(j_2,k) \geqslant D_k \text{ (minimum amount required for the } k^{th} \text{ end-use.)} \qquad \forall k$$

EB $\underline{\delta}$ ($\delta=1,2\cdots 36$) = Constraints with this label are not limiting constraints and are merely energy-balancing equations. These constraints relate the relationship between the energy input and output. This relationship can mathematically written as :

$$\sum_i X(i,j) \cdot e(i,j) - \sum_k Y(j,k) = 0 \qquad \forall j$$

Where, $C(i,j)$ is the efficiency of the $j^{th}$ device using $i^{th}$ energy source.

$CP_1\,j$ : Equations with this label are the limiting constraints related to the maximum capacity available for the $j^{th}$ energy device. Mathematically it is written as :

$$\sum_{k} Y(j,k) - (\text{maximum capacity for one unit of the } j^{th} \text{ device}) * Y_j \leq 0 \quad \forall j$$

A complete list of energy sources/devices and the corresponding reference numbers:

| Energy Sources | Reference Number (index i) |
|---|---|
| Cow dung | 1 |
| Crop residue | 2 |
| Firewood | 3 |
| Charcoal | 4 |
| Coal/coke | 5 |
| Kerosene | 6 |
| Electricity | 7 |
| Diesel | 8 |
| Animal Power | 9 |
| Wind | 11 |
| Solar | 12 |
| Biogas | 13 |

(Note : Number 10 is missing)

## Energy Devices

### Energy Generating Devices

| | Reference Number (index J1) |
|---|---|
| **Bio-gas Plant** | |
| 5 cu.m. | 1 |
| 25 cu.m. | 2 |
| 35 cu.m. | 3 |
| **Diese Gen - Set** | |
| 10 HP | 10 |
| 25 HP | 11 |

| **Energy Utilizing Devices** | **(index $j_2$)** |
|---|---|
| Improved cook stoves (using cowdung and crop residues) | 12 |
| Improved Firewood stove | 13 |
| Kerosene stove | 14 |
| Coal/coke chullah | 15 |
| Bio gas burner | 16 |
| Solar Cooker | 17 |
| Immersion rod | 18 |
| Solar Water Heater | 33 |
| Lantern | 19 |
| Bulb | 20 |
| Mantle | 21 |
| **Diesel Motor** | |
| 5 HP | 22 |
| 8 HP | 23 |
| 10 HP | 24 |

| **Energy Utilizing Device** | **index $j_2$** |
|---|---|
| **Electric Motor** | |
| 3 HP | 25 |
| 5 HP | 26 |
| 8 HP | 27 |
| **Wind Pump** | |
| 5 HP | 28 |
| 10 HP | 29 |
| **Gasifier Pump** | |
| 5 HP | 4 |
| 10 HP | 5 |
| 15 HP | 6 |
| 35 HP Tractor | 34 |
| 51 HP Tractor | 35 |
| Bullock (for ploughing and cart-driving) | 36 |
| 5 HP Electric Thresher | 37 |
| 15 HP Electric Thresher | 38 |
| 15 HP Diesel Thresher | 39 |

(Note : Numbers 5-7, 30-32 are missing)

| **End-Uses** | **Reference Number**<br>index i. |
|---|---|
| Cooking | 1 |
| Lighting | 2 |
| Water heating | 3 |
| Pumping | 4 |
| Threshing and Winnowing | 5 |
| Land Preparation | 6 |
| Transportation | 7 |

## 6.4 Data Requirements and Program Execution:

The following data will have to be identified for the model execution

1. The energy technologies/devices that are available to fulfil the various types of energy needs.
2. Capacity i.e. the maximum amount of energy each technology can deliver per year.
3. The cost of generating the energy : maintenance of equipment and delivery to each end-use.
4. Availability of the various raw materials used by the energy systems.
5. Levels of demand of each type.

Calculation of costs and capacities of Energy Generating Devices is illustrated below:

1. Annual Fixed Cost : Annual fixed cost is assumed to be 25% of capital (fixed cost). It is a sum of 10% depreciation, 12% interest and 3% operation and maintenance.

2. Variable Cost : This cost is calculated according to the following method :

Cost of $i^{th}$ fuel = Rs./Unit (Unit can be kg, lt, kWh etc)

Calorific Value of the $i^{th}$ fuel = x K.Cal/Unit
= x/861 KWH/Unit

Efficiency of the $j^{th}$ device using ith fuel = e(i,j)

Thus energy given for use by burning one unit of $i^{th}$ fuel = x/861 kWh * e(i,j)
= y kWh (say)

Cost of 1KWH of $i^{th}$ fuel = $\frac{\text{Cost of ith fuel}}{y}$ Rs.

Annual Capacities : (an illustration)

Say, we have to calculate annual capacity of the 5 cu.m. bio-gas plant.

Calorific Value of biogas $= 4770$ K.Cal/$m^3$

$$= \frac{4770}{861} \text{ KWH/m}^3$$

$$= 5.55 \text{ KWH/m}^3$$

Total thermal energy available from a 5 cu.m. bio gas plant per day = 27.75 KWH

Assuming that in a year, plant is functional for 250 days, total capacity available from this 5 cu.m. plant is = 6937.5 KWhs.

## Program Execution

Execution of this model is done using LP83 package by Sunset Software. This involves entering data through the Lotus worksheet. The name of the input file created for the test run is FREM1.WKS. It has 110 variables and 85 constraints. For this run, the various Range names (explained in earlier chapters) defined are :

1) 83TITLE 2) 83VARIABLE 3) 83COST 4) 83LOWER
5) 83UPPER 6) 83CONSTRAINT

After creating an input-file with WKS as an extension, for executing this file a single command has to be given

```
LP83 FREM1.WKS.
```

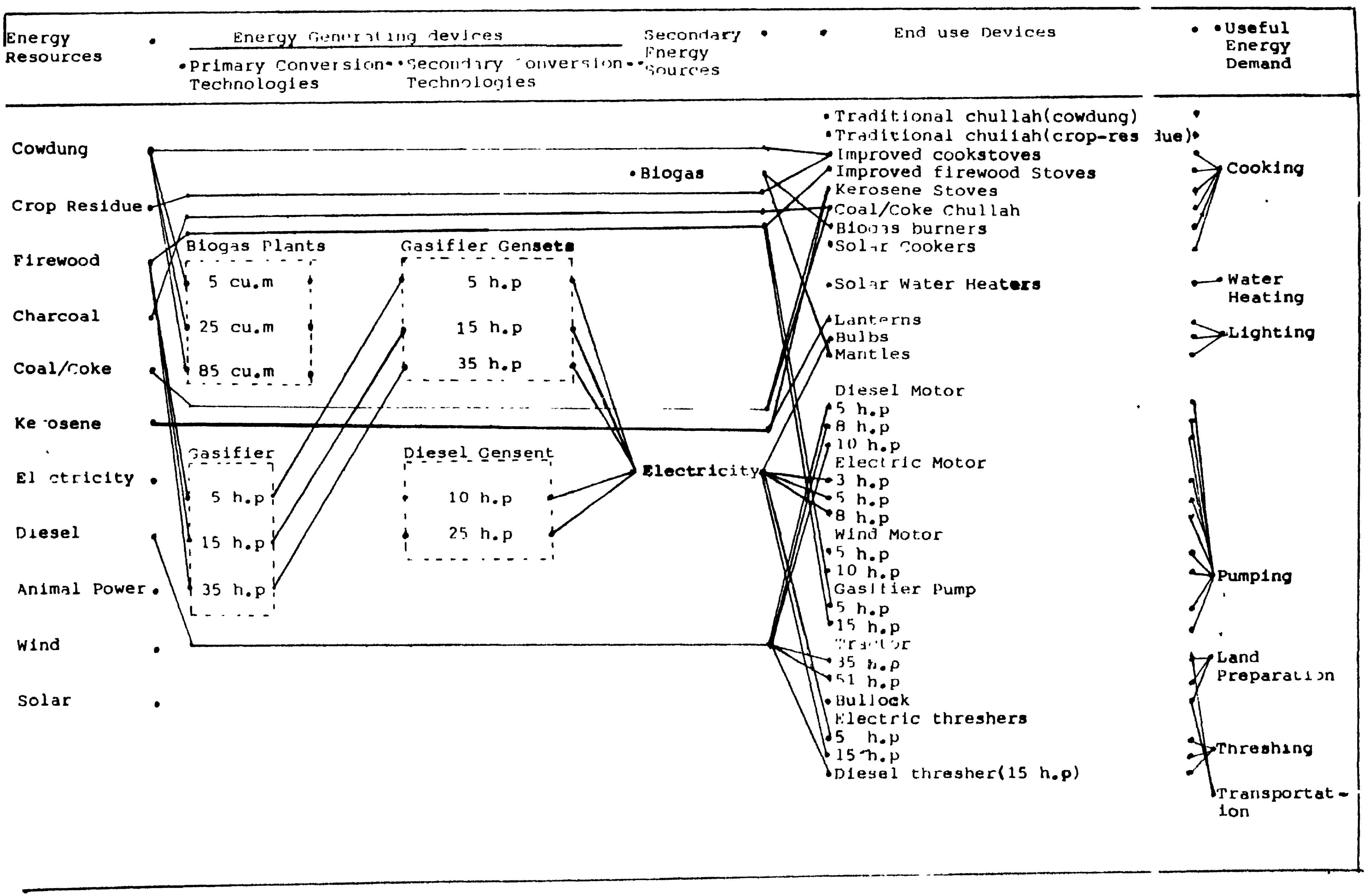
With this command the listing of the input and also the output is given on the console. To store the output in the disk, the command to be given is

```
LP83 FREM1.WKS OUTPUT XXX
```

Where XXX is the filename to be given in which output has to be stored. Test-run output filename TRUN.

Figure6.1: REFERENCE ENERGY SYSTEM NETWORK

(Village level)



# 7. EVALUATION OF RENEWABLE ENERGY TECHNOLOGIES FOR END USES

**7.1 Introduction:** Macro-economic analysis aids decisions related to investments, resource allocation etc. and is essential at national/regional level. Similar tools for helping decision making at the implementation stage are also needed. Questions like, given certain resources for changing the energy pattern for a particular end-use, the choice of adopting source of the (various) renewable energy technology options need to be answered based on the overall local situation. The analysis would take into account the availability of local resources, infrastructure facilities, and social practices as well as the economic viability of new technology. This model helps in making economic analysis of the renewable energy options by comparing with the technology to be replaced.

Table 7.1 lists the renewable energy technologies, end-uses considered, and conventional technology to be substituted. Combinations of these are evaluated in the model.

In case of biogas, windmill and wood gasifier, for a given size of the equipment for renewable energy technology, the size of the conventional technology it would replace is calculated within the program. For solar photovoltaic and solar thermal options, given the size of the equipment for conventional technology to be replaced, the required size of the equipment for renewable technology is computed. Then the investment and operation and maintenance costs are compared to find out whether a technology is feasible. If it is found to be feasible, then its payback period and the Internal Rate of Return (IRR) are computed.

Table 7.1

[ [ TECHNOLOGY ENDUSE PACKAGE ] ]

| RENEWABLE ENERGY TECHNOLOGY | ENDUSE CONSIDERED | CONVENTIONAL TECHNOLOGY TO BE SUBSTITUTED |
|---|---|---|
| 1. Biogas ... | 1. Cooking ... | 1. Fuel Wood/Kerosene etc. |
| | 2. Lighting ... | 2. Kerosene/Electricity |
| | 3. Irrigation... | 3. Electricity/Diesel |
| 2. Windmill ... | 1. Irrigation... | 1. Electricity/Diesel |
| 3. Solar Photovoltaic ... | 1. Lighting ... | 1. Kerosene/Electricity |
| | 2. Irrigation... | 2. Electricity/Diesel |
| 4. Solar Thermal ... | 1. Water heating | 1. Electricity/Fuel Oil |
| | 2. Cooking ... | 2. Fuel Wood/Kerosene etc. |
| 5. Biomass Gasifier ... | 1. Water heating | 1. Fuel oil boiler |
| | 2. Irrigation... | 2. Electricity/Diesel |

## 7.2 Model Description:

After selecting the Renewable energy technology, select one of the end-uses considered, and the conventional technology to be replaced. The feasibility study is carried out after computing the following four parameters.

1. Total investment on the renewable energy technology (I1)
2. Operation and Maintenance cost of the above (OM1)
3. Total investment on the conventional technology (I2) (Equivalent System)
4. Operation and Maintenance cost for the above (OM2)

The following diagram explains results for four possible combinations of results and the conclusions arrived.

| Decision made | Conclusion arrived |
|---|---|
| 1. I1>I2 and OM1>OM2 .... | Technology not feasible |
| 2. I1>I2 and OM1<OM2 .... | Technology may be feasible (Calculates Pay back period and IRR) |
| 3. I1<I2 and OM1>OM2 .... | Unbounded solution |
| 4. I1<I2 and OM1<OM2 .... | Technology very attractive |

Except for case 2, computation of econometric parameters, Payback period and Internal Rate of Return (IRR) are not carried out.

The following steps explain how the econometric parameters are calculated. The payback period is the value of 'i' for which the following equation is satisfied.

$$I1 + \sum_{j=1}^{i} \frac{OM1}{(1+r)^{j}} = I2 + \sum_{j=1}^{i} \frac{OM2}{(1+r)^{j}}$$

Where, r = Annual discount rate on expenditure
i <= S1 S1 = System life
for I1, I2, OM1, OM2 : refer back

Both the operation and maintanence costs include the annual depreciations on their respective investment costs. If the equality is satisfied for a value of 'i' less than 'S1', then payback period is given as range of years corresponding to the two nearest integers to the value of 'i'. If there is no 'i' value less than 'S1' for which the equation is satisfied then it is concluded that the technology is not feasible for the given interest rate. In both the cases, it proceeds further for calculating Internal Rate of Return. The IRR is the value of 'r' calculated using the same equation by assuming the system life as the payback period.

i.e. $$I1 + \sum_{j=1}^{S1} \frac{OM1}{(1+r)^{j}} = I2 + \sum_{j=2}^{S1} \frac{OM2}{(1+r)^{j}}$$

IRR: The value of 'r' for which the above equation is satisifed.

### 7.3 Data Requirements:

Data requirements for the technologies considered and for their potential end-uses are given in Table 7.2. Technical and other parameters for the renewable energy technologies, and for their specified end-uses are listed in Table 7.2a. Each of the parameters for which data are required is allotted a serial number. The order in which the serial numbers are broadly classified is as follows : (i) renewable technologies: biogas, windmill, solar photovoltaics, solar thermal and biomass gasifier; and (ii) end-use applications:

cooking, lighting, waterheating and irrigation. Data requirements for each of the technology /end-use combinations are further listed in Table 7.2b. Here, the serial numbers allotted for each of the parameters in Table 7.2a are listed against each combination considered.

Table 7.2a

| Serial Number | Parameter Description |
|---|---|
| 1. | Biogas plant capacity (in m^3) |
| 2. | Length of biogas piping (in m) |
| 3. | Number of two burner stoves |
| 4. | Number of biogas lamps (20 W) |
| 5. | Number of 20 W lamps to be replaced |
| 6. | Annual average wind speed (in Km/hr) |
| 7. | Rotor blade size (in m) |
| 8. | Power (Hp) of the diesel motor to be replaced |
| 9. | Power (Hp) of the electric motor to be replaced |
| 10. | Global solar radiation (GSR) (in KWhr/m^2) |
| 11. | Latitude (in degrees) |
| 12. | Length of cold water pipe (in m) |
| 13. | Length of hot water pipe (in m) |
| 14. | Capacity of the geyser to be replaed (litres/day at 60 deg C) |
| 15. | Capacity of the fuel oil boiler to be replaced in ltrs/day at 60 deg C with inlet temperature at 20 deg C |
| 16. | Size of the solar cooker (in m^2) |
| 17. | Size of the biomass gasifier (in Hp) |
| 18. | Construction cost of biogas plant/m^3 of biogas |
| 19. | Biogas piping cost/metre |
| 20. | Windmill cost (Rotor-Tower transmission etc.) |
| 21. | Erection and installation cost for the windmill |
| 22. | Investment on hydraulic pump set of compatible size |
| 23. | Cost of investment on PV array/m^2 |
| 24. | Investment on batteries |
| 25. | Investment on PV lamps (20W) |
| 26. | Investment on DC motor pumpset |
| 27. | Investment and installation cost on the collector/m^2 |
| 28. | Expenditure on hot water storage tank |
| 29. | Cold water piping cost/metre |

(contd.)

| Serial Number | Parameter Description |
|---|---|
| 30. | Hot water piping cost/metre |
| 31. | Investment on solar cooker |
| 32. | Investment on gasifier |
| 33. | Annual depreciation on the total investment (in %) |
| 34. | Annual maintenance cost for the total system |
| 35. | Price of 1 kg of firewood |
| 36. | Investment on firewood stoves |
| 37. | Price of 1 litre of kerosene |
| 38. | Investment on kerosene stoves |
| 39. | Price of 1 kg of dung cake |
| 40. | Investment on dung cake stoves |
| 41. | Price of 1 kg of twig stalks |
| 42. | Investment on twig stalk stoves |
| 43. | Expenditure on a two burner stove and a manometer |
| 44. | Expenditure on a biogas lamp (20W) |
| 45. | Price of wet dung/kgm |
| 46. | Investment on kerosene lamps (20 W) |
| 47. | Annual maintenance cost for kerosene lamps |
| 48. | Investment for electric lighting |
| 49. | Annual maintenance cost for electric lamps |
| 50. | Investment on biogas pumpset |
| 51. | Investment on producer gas pumpset |
| 52. | Investment on producer gas boiler |
| 53. | Price of electricity/kWhr |
| 54. | Investment on electric geyser |
| 55. | Annual maintenance cost of electric geyser |
| 56. | Investment cost of fuel oil boiler |
| 57. | Price of fuel oil per kg |
| 58. | Annual maintenance cost of the fuel oil boiler |
| 59. | Investment on electric pump set |
| 60. | Annual maintenance cost for electric pump set |
| 61. | Investment on diesel pumpset |
| 62. | Price of diesel per litre |
| 63. | Annual maintenance cost of diesel pumpset |
| 64. | Price of 1 tonne of nitrogen fertilizer |
| 65. | Price of 1 kg of biomass fuel for gasifier |

Table 7.2b

| Renewable Energy Technology | Enduse Choosen | Conventional technology to be substituted | Sl.Nos. of the Parameters needed |
|---|---|---|---|
| BIOGAS | Cooking | Fuel Wood Stove | 1,2,3,18,19,33,34,35,36,43,45,64 |
| | | Kerosene Stove | 1,2,3,18,19,33,34,37,38,43,45,64 |
| | | Dung Cake Stove | 1,2,3,18,19,33,34,39,40,43,45,64 |
| | | Twig Stalk Stove | 1,2,3,18,19,33,34,41,42,43,45,64 |
| | Lighting | Kerosene Lamp | 1,2,4,18,19,33,34,37,44,45,46,47,64 |
| | | Electric Lamp | 1,2,4,18,19,33,34,44,45,48,49,53,64 |
| | Irrigation | Electric Pump Set | 1,2,18,19,33,34,45,50,53,59,60,64 |
| | | Diesel Pump Set | 1,2,18,19,33,34,45,50,61,62,63,64 |
| WINDMILL | Irrigation | Electric Pump Set | 6,7,20,21,22,33,34,53,59,60 |
| | | Diesel Pump Set | 6,7,20,21,22,33,34,61,62,63 |
| SOLAR PHOTOVOLTAICS | Lighting | Kerosene Lamps | 5,10,11,23,24,25,33,34,37,46,47 |
| | | Electric Lamps | 5,10,11,23,24,25,33,34,48,49,53 |
| | Irrigation | Electric Pump Set | 9,10,11,23,26,33,34,53,59,60 |
| | | Diesel Pump Set | 8,10,11,23,26,33,34,61,62,63 |

(Contd.)

| Renewable Energy Technology | Enduse Choosen | Conventional technology to be substituted | Sl.Nos. of the Parameters needed |
|---|---|---|---|
| SOLAR THERMAL | Water Heating | Electric Geyser | 10,11,12,13,14,27,28,29,30,3 34,53,54,55 |
| | | Fuel Oil Boiler | 10,11,12,13,15,27,28,29,30,3 34,56,57,58 |
| | Cooking | Fuel Wood Stove | 10,16,31,33,34,35,36 |
| | | Kerosene Stove | 10,16,31,33,34,37,38 |
| | | Dung Cake Stove | 10,16,31,33,34,39,40 |
| | | Twig Stalks Stove | 10,16,31,33,34,41,42 |
| BIOMASS GASIFIER | Water Heating | Fuel Oil Boiler | 17,32,33,34,52,56,57,58,64,6 |
| | Irrigation | Electric Pump Set | 17,32,33,34,51,53,59,60,64,6 |
| | | Diesel Pump Set | 17,32,33,34,51,61,62,63,64,6 |

## 7.5 Program Execution :

After deciding the renewable energy option, end-use and technology to be replaced, from Table 7.2 data needed for execution can be found out and necessary data can be collected. Program execution begins by typing

```
TECHUSE<R>
```

then Table 7.1 will be displayed and you can choose renewable energy technology option by typing its serial number as:

```
==>Select Renewable Energy Technology (1,2,3,4,5) ? 1<R>
```

The next screen of display list out the technology related parameters for the renewable energy technology selected.

```
¶                                                                    ¶
                [ [ TECHNOLOGY  RELATED PARAMETERS ] ]

TECHNOLOGY = [ BIOGAS ]

      1. Dung needed (kg/m^3) for Biogas (80% Moisture) = 25
      2. Water needed in ltrs/m^3 of biogas = 25
      3. Manure in kg/m^3 of Biogas = 9.75
      4. FRR for cooking (ltr of Kerosene/m^3) = .341
      5. FRR in Kg of Wood per m^3 of biogas = 2.872
      6. FRR in Kg of Dung Cake per m^3 of biogas = 6.338
      7. FRR in kg of Twigs Stalks per m^3 of biogas = 3.649
      8. FRR for irrigation (kWhr of electricity/m^3) = 1.1
      9. FRR in Ltr of diesel per m^3 of biogas = .529
     10. FRR for lighting (kWhr of electricity/m^3) = .4
     11. FRR for lighting (ltr of kerosene/m^3) =
     12. System Life (in Years) = 10
     13. Cattle needed/m^3 of Biogas = 2
    Is this OK ?

To Change the Value of a Parameter
Type its Sl. No. Otherwise <R>  ---> ?
¶                                                                    ¶
```

The values supplied here are fairly accurate. Still the package allows you to change these values for any of the parameters. It is done by typing serial number of the parameter and <R> for the question in the last line of this display and entering the new value in the next screen. The new value is registered temporarily for the current execution. Press <R> if you do not want to change any value or after registering new values for the parameters, and it will take you to the following screen display.

```
¶                                                                   ¶
TECHNOLOGY
[ BIOGAS ]

END-USE                  CONVENTION TECHNOLOGY
CONSIDERED               TO BE SUBSTITUTED


1. Cooking     ...       1. Fuel Wood/Kerosene/Dung Cake/Twig Stalks

2. Lighting    ...       2. Kerosene/Electric Lamp

3. Irrigation ...        3. Electric/Diesel Pump Set

     Select Enduse (1,2,3) ? 1<R>

¶                                                                   ¶
```

Now the display shows you the list of enduses considered in this package for the selected technology. Select one of the enduses by typing its serial number and <R>. In a similar way, you need to select the conventional technology to be substituted by the renewable energy technology for the selected enduse in the following screen.

```
¶                                                           ¶
     TECHNOLOGY                     END-USE
     [ BIOGAS ]                     [ COOKING ]

CONVENTION TECHNOLOGY TO BE SUBSTITUTED

1. Fuel Wood Stove

2. Kerosene Stove

3. Dung Cake Stove

4. Twig Stalks Stove

   Select Technology to be Substituted (1,2,3,4) ? 2<R>
¶                                                           ¶
```

In the next screen, it asks values for local parameters and/or parameters related to the enduses. Some or all of these parameters are used to find out the size or the measure of the equipment needed for equivalent systems in renewable and conventional technologies. This helps the user to avoid ambiguous combinations.

The following screen takes example from biogas.

```
¶                                                              ¶

TECHNOLOGY            END-USE               TECHNOLOGY REPLACED
[ BIOGAS ]            [ COOKING ]           [ KEROSENE STOVE ]

         [ [  ESTIMATION OF EQUIVALENT SYSTEMS ] ]

Biogas Plant Capacity (in m 3) ? 2<R>

Length of Biogas Piping (in m) ? 5<R>

Number of Two burner Stoves ? 1<R>

This can replace the kerosene stove(s) consuming
.682 litres per day.

Use <PrtSc> to print  this.
Otherwise (or after that) press any key.

¶                                                              ¶
```

The message in the above screen helps the user to decide about size or the number of stoves the specified biogas plant can replace.

Through the following three screens of dialogue, the values for Investment, Operation and Maintenance, and Return Related Parameters are entered.

```
¶                                                                 ¶
 TECHNOLOGY              END-USE             TECHNOLOGY REPLACED
 [ BIOGAS ]              [ COOKING ]         [ KEROSENE STOVE ]

         [ [ INVESTMENT RELATED PARAMETERS ] ]

Construction Cost of Biogas Plant/m^3 of Biogas ? 2000<R>

Biogas Piping Cost/metre ? 5<R>

Expenditure on a Two burner Stove and a Manometer ? 300<R>
¶                                                                 ¶
```

```
¶                                                                 ¶
TECHNOLOGY          END-USE            TECHNOLOGY REPLACED
[ BIOGAS ]          [ COOKING ]        [ KEROSENE STOVE ]

       OPERATION & MAINTANANCE RELATED PARAMETERS

Price of Wet Dung/Kgm ? 0.0<R>

Annual Maintenance Cost for the Total system ? 100<R>
¶                                                                 ¶
```

```
¶                                                                 ¶
TECHNOLOGY            END-USE              TECHNOLOGY REPLACED
[ BIOGAS ]            [ COOKING ]          [ KEROSENE STOVE ]

                 RETURN RELATED PARAMETERS

Price of 1  Tonne of Nitrogen Fertilizer ? 5000<R>

Price of 1 Litre of Kerosene ? 4 = 2.6<R>

Investment on Kerosene Stoves ? 200<R>
¶                                                                 ¶
```

Now the package is ready with all the parameters needed to carry out the feasibility study. Enter the value for Annual discount rate on expenditure and Annual depreciation rate on investment in the following screen. Along with Investment Cost and Operation and Maintanance

Cost per year the feasibility study results are also displayed after that. The further display in the same screen gives you the values of the economic parameters, if calculated.

```
¶                                                                    ¶
TECHNOLOGY             END-USE                TECHNOLOGY REPLACED
[ BIOGAS ]             [ COOKING ]            [ KEROSENE STOVE ]

Annual discount rate on expenditure(in %) ? 5<R>

Annual depreciation rate on investment (in %) ? 5<R>

                                   Renewable      Conventional

Investment cost            ....     4025            200

Operation and Maintanance
cost/year                  ....     1977.5          1005.72

Technology not feasible....

Any more Execution (Y/N) ?
¶                                                                    ¶
```

If you type N<R> for the question in the last time the program terminates here. If you want to start the execution for some more combinations of Renewable Energy Technology, End-use and the conventional technology to be replaced, type Y<R>.

Remarks : Data on the technical and economic parameters for the various renewable energy technologies considered, and the conventional systems that they may substitute, are compiled from the existing literature on the subject. For further information, please contact the Tata Energy Research Institute, New Delhi, India.

## HINTS:

1. Both the inputs and the results of the executions are not saved in any file. Where the following message appears on the screen:

   ```
   ==> Use <PrtSc> to print this
   ==> Otherwise (or after that) Press any key
   ```

   You can echo the display to the printer by pressing ⇑ key and <PrtSc> simultaneously.

   All the necessary screens have this provision and the print out taken while execution forms a good input-output printout.

2. A question for a numeric value will be repeated if a non-numeric entry is done.

3. To abort the program at any stage press <Ctrl> and <C> simultaneously.

# 8. ENERGY CONSERVATION IN BUILDINGS

8.1 Introduction: One of the major areas for energy conservation is in energy efficient designs of buildings. Developing countries in Asia-Pacific region are involved in large scale construction activity and this offers a potential area for energy conservation through proper design of buildings. Substantial portion of heating and cooling requirements in a building can also be met by the use of renewable energy techniques. Hence a module on energy conservation in buildings is included here to illustrate the basic principles involved in the design of energy efficient buildings by using solar heating.

In principle, architectural design can be developed for a building to maximise solar gains in the winter (and minimise them in the summer) to reduce heating (and cooling) loads that must be met by other means to keep the buildings at a comfortable temperature. Elements in the building (walls, roofs, floors) may be constructed to have high heat capacity to store thermal energy and reduce interior temperature variations. There is no substitute for good energy conserving architectural design which optimises the solar gains in the buildings.

This module is a demonstration tool to show the effect of different building designs and different building elements on heating loads. In particular, it computes the reduction in heating load achieved by incorporating a Trombe wall in the building.

8.2 Model Description: This package uses the Degree-day method to calculate the heating loads. The monthly space heating load is calculated using the formula.

$$L = (UA)_h \, DD$$

where,

DD : The number of Degree-days in the month. The Degree-day data is readily available for some countries. Otherwise, DD is calculated by summing up the difference between $18.3^\circ$C and the mean daily ambient temperature. The summing is carried out only for the days for which mean ambient temperature is less than $18.3^\circ$C. The difference between $24^\circ$C and $18.3^\circ$C allows for ordinary levels of internal heat energy generation in the building.

$(UA)_h$: Loss Coefficient - Area product for the building. This is calculated by summing up the UA values of the individual components in the building like walls, roofs, doors and windows. The heat loss through the floor is neglected here. Heating load due to the air infiltration is also taken into account.

Heating loads can be reduced by providing insulation, airspaces etc. in the building elements which decreases $(UA)_h$ value of the building. Alternatively, or in addition to that, a collector-storage wall (Trombe Wall) reduces the heating load considerably. The Trombe wall or collector-storage wall is a high capacitance solar collector coupled directly to the space to be heated. Solar radiation is absorbed on the outer surface of the wall. Energy is transfered from the room side of the wall to the spaces to be heated, by convection and radiation. Energy can also be transfered to the space inside by circulating air through the gap between the wall and glazing through openings at the top and bottom of the wall.

In the first set of calculations the program computes the heating loads for the month selected for two designs, one with ordinary construction components and the other with energy conserving construction components. In addition to that it calculates the heating loads of the above two building designs after substituting the South (or North) Wall by the Trombe (Collector-Storage) Wall.

The subsequent calculations of heating loads are carried out for the construction composition of your choice for the same building and the effect of Trombe wall on that. For this you need to input the values of k (thermal conductivities) and X (thickness) of the individual members like concrete, brick etc. for all the building elements such as walls, roofs and so on. k-Values for some of the standard building materials are given in Table 8.2.

8.3 Data Requirements : The monthly average daily solar radiation of the selected month is needed for the Trombe wall calculation. This along with the degree-day data or ambient temprature data needed in the absence of degree-day data for any of the 12 months is generally available with meteorological stations.

The following table explains the two building designs, one with ordinary construction components and the other with energy conserving construction components for which the heating loads are computed in the first set of calculations.

Table 8.1 : U Values for some building elements

| Building Element | Composition and U value | | | |
|---|---|---|---|---|
| | Without Insulation | U Value (W/m$^2$°C) | With Insulation | U Value (W/m$^2$°) |
| Wall | Common brick,8"<br>Gypsum Wallboard,0.5" | 1.96 | Common Brick,8"<br>Airspace,0.75"<br>Gypsum wallboard,0.5" | 0.718 |
| Roof | Lightweight aggregate plaster,0.75"<br>Concrete slab light weighted aggregate,2" | 1.636 | Lightweight aggrgate plaster,0.75"<br>Concrete slab light wighted aggregate,2" with airspace,rigid roof deck insulation and builtup roofing | 0.636 |
| Windows | Single glazed | 6.000 | Double glazed, 12 mm gap | 3.200 |
| Door | Oak, 4" | 0.7847 | Oak, 4" | 0.7847 |

Table 8.2 : k-values for some Standard Building Materials

| Material | Thermal conductivity k, W/m$^{o}$C |
|---|---|
| Common brick | 0.7190 |
| Concrete | 1.7300 |
| Asbestos cement | 0.3190 |
| Gypsum plaster | 0.1700 |
| Oak (16% wet) | 0.1600 |
| Pine (15% wet) | 0.1380 |
| Corkboard, dry | 0.0418 |
| Mineral wool | 0.0346 |
| Polystyrene | 0.0346 |
| Polymethane foam(rigid) | 0.0245 |
| Air | 0.0260 |

8.4 Programme Execution: All the data for this package is entered by the user interactively during the execution of the program. A typical execution of the program proceeds as below and the values are given just for illustrative purpose and do not corespond to any real situation. Type the following to execute program on energy conservation in buildings:

```
BUILDING<R>
```

The first screen of dialogue proceeds as follows:

```
==>                    [LOCAL PARAMETERS]
==> Location: Enter N (orthern) or S (outhern hemisphere) ? N<R>
==> Latitude (in degrees) ? 30<R>
==> Month of Interest: Enter the No. of the month? 9<R>
==> Degree Days (DD) data available or not (Y/N) ? Y<R>
```

If you type Y<R> the dialogue continues as follows:

```
==> Number of Degree Days in the month of September ? 9<R>
```

and it takes you to the BUILDING DETAILS screen.

If you type N<R> then you need to input the ambient daily mean temperature for all the days for the month selected. And it is done as explained below :

```
¶                                                        ¶
 Computing  number  of  degree days for  the  month  of
 February
Average Temperature on February 1
Enter value here (in degree celsius) 15.2<R>
                   o
                   o
                   o
¶                                                        ¶
```

Enter the value of average daily temperature for all the days in the selected month.

Now to input the building details the dialogue proceeds as follows:

```
¶                                                        ¶
                  [ BUILDING DETAILS ]
          Length in metres, Areas in metre square
 Height of the building ? 3<R>
 Length of the building in the North-South direction ? 4<R>
                           the  East-West  direction ? 4<R>
 Area of the Doors ? 2<R>
 Area of the Windows ? 2<R>
 Air  change per hour (in the units of Building  Volume)[3] ? 2<R
¶                                                            ¶
```

Now to input the paramter needed for Trombe Wall calculation the dialogue is as follows:

```
¶                                                              ¶
                   [TROMBE WALL PARAMETER]
          South Wall is substituted by the Trombe Wall

Monthly average  Daily Solar Radiation (in Joules/m^2) ? 4<R>

Say snow is there or not (Y/N) ? N<R>
¶                                                              ¶
```

The program is then ready with all the data needed for calculating the heating loads with two sets of designs for wall, roof and windows one with insulations and the other without insulation (refer table 8.1). In the next screen the results are displayed as :

```
¶                                                              ¶
                        [ HEATING LOADS ]
                        (in  mega joules)
                   Without insulation   With insulation

                   Common brick, 8"     Common brickm 8"
Wall design    ... Gypsum Wall          Air space, 0.75"
                   board,0.5"           Gypsum wall board,0.5"

                   Plaster, 0.75"       Plaster, 0.75"
Roof design    ... Concrete slab, 2"    Air space, Roof insula-
                                        tion, Concrete slab, 2"

Door design    ... Oak wood, 4"         Oak wood, 4"

Window design... Single glazed          Double glazed
                                        (12mm air gap)
Heating load ... XXX...                      XXX...

Heating load ... XXX...                      XXX...
(with Trombe wall in South)

Press any key to continue?
¶                                                              ¶
```

If you proceed further the following message appears on the screen:

```
¶                                                              ¶
Would you like to carryout ...

      Heating load calculations for
      your choice of composition

                    Say Y (es) or N (o) ? Y<R>
¶                                                              ¶
```

If you say N(o) by typing N<R> the execution stops here. Say Y(es) by typing Y<R> if you want to compute heating loads for your choice of compositions for walls, roof, door and windows.

Here you need to fill in k (thermal conductivity) and the thickness of various elements to design the wall, roof and door. This is done in the next three screens of dialogue.

```
¶                                                              ¶
 Number  of members in the Wall ?  5<R>

 Wall design ...

    Member        k - Value (in W/m deg C)      Thickness
     No.            Thermal Conductivity         (in m)

     1                 0.7190<R>                 0.25<R>

     2                 1.7130<R>                 0.10<R>

     3                 0.0260<R>                 0.05<R>

     4                 0.3190<R>                 0.05<R>

     5                 0.0418<R>                 0.05<R>
¶                                                              ¶
```

In the same way the roof and door are designed.

```
¶                                                              ¶
Number of Members in the Roof ? 3<R>
Roof design ...
    Member        k - Value (in W/m deg C)       Thickness
     No.            Thermal Conductivity           (in m)
      1                 0.3190<R>                 0.10<R>
      2                 0.1700<R>                 0.05<R>
      3                 0.0418<R>                 0.10<R>
¶                                                              ¶
```

```
¶                                                              ¶
Number of Members in the Door ? 1<R>
Door design ...
    Member        k - Value (in W/m deg C)       Thickness
     No.            Thermal Conductivity           (in m)
      1                 0.138<R>                   0.1<R>
¶                                                              ¶
```

For the window design there are two options available. You have to select one of them and is done in the following way.

```
¶                                                              ¶
   Window design ...
      1. Single glazed
      2. Double glazed with 12 mm airgap
           Select (1,2) ? 2<R>
¶                                                              ¶
```

Now the heating loads calculated for the given composition will be shown in the screen as follows:

---

```
¶                                                                    ¶
                              . [ HEATING LOAD ]
                                (in mega joules)
                            for the given composition
Heating load ...

      Without Trombe Wall           ...           XXX...

      With Trombe wall in           ...           XXX...
      South (without night
      insulation)

      With Trombe wall in           ...           XXX...
      South (with night
      insulation)

Any more composition (s) (Y/N) ?
¶                                                                    ¶
```

---

If you type N<R> for the question asked in the last line of the above display the execution stops here. If you type Y<R> it proceeds for calculating heating loads for one more choice of your design.

**HINTS:**

1. Both the inputs and the results of the executions are not saved in any file. Where the following message appears on the screen:

   ```
   ==> Use <PrtSc> to print this
   ==> Otherwise (or after that) Press any key
   ```

   You can echo the display to the printer by pressing ⇑ key and <PrtSc> simultaneously.

   All the necessary screens have this provision and the print out taken while execution forms a good input-output printout.

2. A question will be repeated if a non-numeric entry is done

3. To abort the program at any stage press <Ctrl> and <C> simultaneously.

# APPENDIX 3.1

## Sample Data and Output

Table3.1 : Data for X and Y Vectors in Input-Output Model for India

| S.NO. | SECTORS | Y | X |
|---|---|---|---|
| | (i) Energy Sector x $10^9$ kCal | | |
| 1. | ELECTRICITY | 29.29 | 79555.75 |
| 2. | COKING COAL | 0.00 | 164061.10 |
| 3. | NON-COKING COAL | -9300.00 | 378276.00 |
| 4. | LIGNITE | 0.00 | 6296.50 |
| 5. | CRUDE OIL | -169431.70 | 101848.11 |
| 6. | LPG | -47.00 | 470.47 |
| 7. | NAPHTHA | 22.80 | 27531.00 |
| 8. | MOGAS | 245.30 | 16880.34 |
| 9. | ATF/JET FUEL | -442.00 | 12199.20 |
| 10. | KEROSENE | -14663.00 | 29413.80 |
| 11. | HSD | -19720.80 | 88156.46 |
| 12. | LDO | -387.00 | 14342.70 |
| 13. | FUEL OILS | -7582.00 | 65332.40 |
| 14. | OTHER PETROLEUM PRODS. | -1523.25 | 3560.18 |
| 15. | NATURAL GAS | 0.00 | 8806.30 |
| 16. | CHARCOAL | 0.00 | 4169.20 |
| 17. | DUNG | 0.00 | 152740.14 |
| 18. | CROP WASTE | 0.00 | 107144.33 |
| 19. | FIREWOOD | 0.00 | 450322.85 |
| | (ii) Energy Product Sectors x $10^9$ kCal | | |
| 20. | LIGHTING | 1200.72 | 1896.62 |
| 21. | COOKING | 651.94 | 694.36 |
| 22. | HEATING | 154.21 | 243.97 |

Contd...2

| S.NO | SECTORS | Y | X |
|---|---|---|---|
| 23. | STREET LIGHTING | 0.00 | 149.60 |
| 24. | PUBLIC WATER WORKS | 0.00 | 2275.40 |
| 25. | FEEDSTOCKS (ELEC) | 0.00 | 33614.40 |
| 26. | FEEDSTOCKS (COAL) | 0.00 | 5956.70 |
| 27. | FEEDSTOCKS (NAPHTHA) | 0.00 | 149435.63 |
| 28. | FEEDSTOCKS (FO) | 0.00 | 41869.05 |
| 29. | FEEDSTOCKS (NAT. GAS) | 0.00 | 17616.16 |
| 30. | MOTIVE POWER (RURAL) | 0.00 | 0.00 |
| 31. | MOTIVE POWER (ROAD) | 1184970.00 | 5865510.00 |
| 32. | MOTIVE POWER (RAIL) | 0.00 | 4816980.00 |
| 33. | MOTIVE POWER (AIR) | 0.00 | 187270.00 |
| 34. | MOTIVE POWER (WATER) | 0.00 | 144260.00 |
| 35. | MOTIVE POWER (LDO PUMP) | 0.00 | 0.00 |
| 36. | PROCESS HEATING | 0.00 | 672713.49 |
| 37. | ELECTRIC DRIVE | 0.00 | 851959.48 |
| 38. | ORE REDUCTION | 0.00 | 24745.00 |
| 39. | IRRIGATION | 0.00 | 75417.67 |
| 40. | HARVESTING | 0.00 | 0.00 |
|  | (iii) Non-Energy Sectors: ($10^6$ Rs.) |  |  |
| 41. | PADDY | 80165.50 | 89267.00 |
| 42. | WHEAT | 33946.00 | 42499.10 |
| 43. | OTHER CEREALS | 30424.50 | 35970.90 |
| 44. | PULSES | 11594.00 | 14036.20 |
| 45. | SUGARCANE | 2435.70 | 18773.60 |
| 46. | JUTE | 172.20 | 2297.90 |

Contd...3

| S.NO. | SECTORS | Y | X |
|---|---|---|---|
| 47. | COTTON | 1212.40 | 14227.60 |
| 48. | PLANTATION | 72026.60 | 134616.30 |
| 49. | MISC. FOOD PRODUCTS | 122820.20 | 145308.10 |
| 50. | FORESTRY | 8889.90 | 14424.30 |
| 51. | FISHING | 7999.70 | 9496.00 |
| 52. | MINERALS | -4025.80 | 4428.20 |
| 53. | SUGAR | 14694.30 | 16471.80 |
| 54. | GUR & KHANSARI | 18977.80 | 19564.90 |
| 55. | HYDROGEN OIL | 6448.00 | 12016.10 |
| 56. | EDIBLE OIL | 9581.50 | 10899.60 |
| 57. | COTTON TEXTILES | 30297.80 | 42877.20 |
| 58. | OTHER TEXTILES | 47878.90 | 71728.00 |
| 59. | WOOD PRODUCTS | 5156.80 | 16805.90 |
| 60. | PAPER & PRODUCTS | 310.30 | 8655.50 |
| 61. | MISC. MANUFACTURERS | 38622.10 | 66785.80 |
| 62. | SYNTHETICS | 202.80 | 12893.70 |
| 63. | INORGANIC CHEMICALS | -426.50 | 6572.90 |
| 64. | ORGANIC CHEMICALS | -1040.00 | 1398.40 |
| 65. | FERTILISERS | -5917.10 | 23297.50 |
| 66. | INSECTICIDES | 221.90 | 2259.80 |
| 67. | DRUGS & PHARMACEUTICALS | 154.80 | 20474.20 |
| 68. | COSMETICS | 6863.20 | 8810.60 |
| 69. | OTHER CHEMICALS | 1389.20 | 9826.90 |
| 70. | REFRACTORY | 29.00 | 7487.00 |

Contd...4

| S.NO. | SECTORS | Y | X |
|---|---|---|---|
| 71. | CEMENT | -642.70 | 4660.80 |
| 72. | OTHER NON METALLIC PRODUCTS | 8048.20 | 20164.80 |
| 73. | I&S, FERROALLOYS | -3521.40 | 24791.50 |
| 74. | I&S, COSTINGS | 2117.20 | 5906.50 |
| 75. | NON-FERROUS METALS | -2765.50 | 14960.10 |
| 76. | METAL PRODUCTS | 10984.60 | 25910.80 |
| 77. | TRACTORS ETC. | 3477.50 | 4403.00 |
| 78. | NON-ELECTRICAL MACHINERY | 21286.70 | 31400.70 |
| 79. | ELECTRIC MOTORS | 2545.60 | 2969.70 |
| 80. | ELECTRIC CABLES | 3379.70 | 4220.60 |
| 81. | OTHER ELEC. MACHINERY | 8574.90 | 11552.90 |
| 82. | SHIPS & BOATS | 504.20 | 1346.00 |
| 83. | RAIL | 4218.00 | 6557.50 |
| 84. | MOTOR VEHICLE | 11936.20 | 16239.70 |
| 85. | OTHER TRANS. EQUIPMENT | 4351.90 | 7064.50 |
| 86. | CONSTRUCTION | 120178.00 | 154566.10 |
| 87. | GAS & WATER SUPPLY | 4793.70 | 6785.10 |
| 88. | RAILWAYS | 10648.50 | 19742.50 |
| 89. | OTHER TRANSPORT | 32520.50 | 81034.20 |
| 90. | SERVICES | 271614.20 | 482204.20 |

## Table 13.2 Sub-Matrix $A_{ss}$

|  | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 |  | LECTRICITY | OKING COAL | OKING COAL | LIGNITE | CRUDE OIL | LPG | NAPHTHA | MOGAS | F/JET FUEL | KEROSENE | HSD |
| 2 | ELECTRICITY | .07942016 | .00220832 | .00236547 | 0 | .00103635 | .00180695 | .00186226 | .00190162 | .00192144 | .00183213 | .00192079 |
| 3 | COKING COAL | 0 | .17605636 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | NON-COKING COAL | 1.8873557 | .03264028 | .03303144 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | LIGNITE | .07914576 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | CRUDE OIL | 0 | 0 | 0 | 0 | 0 | 1.0651381 | 1.0651314 | 1.0637723 | 1.0651314 | 1.0113639 | 1.0406472 |
| 7 | LPG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | NAPHTHA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | MOGAS | 0 | 0 | 0 | 0 | .00021641 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | ATF/JET FUEL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | KEROSENE | .01925442 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | HSD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | LDO | .00959390 | .00123247 | .00124724 | 0 | .00438103 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | FUEL OIL | .27396915 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | OTHER PET.PR. | .06389771 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | NATURAL GAS | .03682826 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | CHARCOAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | DUNG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | CROP WASTE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | FIREWOOD | .00046194 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

|  | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|
| 1 | LDO | FUEL OIL | ER PET.PR. | ATURAL GAS | CHARCOAL | DUNG | CROP WASTE | FIREWOOD |
| 2 | .00182114 | .00206391 | .01349089 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | .98194205 | 1.0768372 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | .29877474 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Table A.3: Sub-Matrix $A_{sp}$

```
  |      A       ||    B    ||    C    ||    D    ||    E    ||    F    ||    G    ||    H    ||    I    ||    J    ||    K    ||    L    |
 1|               M.LIGHTINGM.COOKINGM.HEATINGT LIGHTINGATER WORKSTOCK(ELEC) FS (COAL)S(NAPHTHA)(FUEL OIL)S(NAT GAS)TIVE RURAL
 2|    ELECTRICITY 4.4370354 .16026269 11.082920 4.0908422 .53269755 .18429412         0         0         0         0
 3|    COKING COAL         0 4.3247739 .68528917         0         0         0         0         0         0         0
 4|NON-COKING COAL         0         0         0         0         0         0 .18399449         0         0         0
 5|        LIGNITE         0         0         0         0         0         0         0         0         0         0
 6|      CRUDE OIL         0         0         0         0         0         0         0         0         0         0
 7|            LPG         0 6.8102292 .33803336         0         0         0         0         0         0         0
 8|        NAPHTHA         0         0         0         0         0         0         0 .18408063         0         0
 9|          MOGAS         0         0         0         0         0         0         0         0         0         0
10|   ATF/JET FUEL         0         0         0         0         0         0         0         0         0         0
11|       KEROSENE 13.594632 19.964773 11.880190         0         0         0         0         0         0         0
12|            HSD         0         0         0         0         0         0         0         0         0         0
13|            LDO         0         0         0         0         0         0         0         0         0         0
14|      FUEL OILS         0         0         0         0         0         0         0         0 .18753709         0
15| OTHER PET.PROD         0         0         0         0         0         0         0         0         0         0
16|    NATURAL GAS         0         0         0         0         0         0         0         0         0 .18422290
17|       CHARCOAL         0 5.0576070 2.6945936         0         0         0         0         0         0         0
18|           DUNG         0 211.55957 23.944091         0         0         0         0         0         0         0
19|     CROP WASTE         0 144.08794 29.083207         0         0         0         0         0         0         0
20|       FIREWOOD         0 621.67075 76.332336         0         0         0         0         0         0         0
```

```
  |    M    ||    N    ||    O    ||    P    ||    Q    ||    R    ||    S    ||    T    ||    U    ||    V    |
 1|OTIVE ROADOTIVE RAILMOTIVE AIRTIVE WATERMOTIVE LDOSS HEATINGTRIC DRIVE REDUCTIONIRRIGATIONHARVESTING
 2|         0 .00041885         0         0                   0 .04514569         0 .15339509         0
 3|         0         0         0         0                   0         0 5.3345198         0         0
 4|         0 .01179162         0 .07126022           .22306909         0         0         0         0
 5|         0         0         0         0                   0         0         0         0         0
 6|         0         0         0         0                   0         0         0         0         0
 7|         0         0         0         0                   0         0         0         0         0
 8|         0         0         0         0                   0         0         0         0         0
 9| .00241978         0         0         0                   0         0         0         0         0
10|         0         0 .06750254         0                   0         0         0         0         0
11|         0         0         0         0                   0         0         0         0         0
12| .01221497 .00197078         0 .00449189                   0         0         0 .18396299         0
13|         0         0         0 .00685568                   0         0         0 .15722111         0
14|         0         0         0 .01888812           .05694067         0         0 .01985742         0
15|         0         0         0         0                   0         0         0         0         0
16|         0         0         0         0                   0         0         0         0         0
17|         0         0         0         0                   0         0         0         0         0
18|         0         0         0         0                   0         0         0         0         0
19|         0         0         0         0                   0         0         0         0         0
20|         0         0         0         0                   0         0         0         0         0
```

## Table 3.4 Sub-Matrix $A_{pi}$

|  | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 |  | PADDY | WHEAT | OTHER CERE | PULSES | SUGARCANE | JUTE | COTTON | PLANTANTIO | MISC.FOOD | FORESTRY | FISHING |
| 2 | COMM. LIGHTING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | COMM. COOKING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | COMM. HEATING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | STREET LIGHTING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | PUB.WATER WORK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | FEEDSTOCKS(ELEC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | " (COAL) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | " (NAPTHA) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | " (FO) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | " (NAT.GAS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | MOTIVE POWER(R) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | " (ROAD) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | " (RAIL) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | " (AIR) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | " (WATER) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | " (LDO PUMP) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | PROCESS HEATING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .14843632 | 0 | 0 |
| 19 | ELECTRIC DRIVE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .16007318 | 0 | 0 |
| 20 | ORE REDUCTION | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | IRRIGATION | .21444445 | .21444445 | .21444445 | .21444445 | .21444445 | .21444445 | .21444445 | .21444445 | 0 | 0 | 0 |
| 22 | HARVESTING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

|  | M | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MINERALS | SUGAR | GUR&KHANSA | HYDROGEN | EDIBLE OIL | COTTON TEX | OTHER TEXT | WOOD PRODU | PAPER&PROD | MISC.MANFG | SYNTHETICS | INORGANIC |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.1140897 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0 | .39838998 | .00978145 | .69809922 | .20625619 | 1.8756166 | .40528594 | .06420811 | 7.2458416 | .01133894 | 2.1613315 | 2.2954647 |
| 19 | 0 | .52576203 | .00238509 | .65347242 | .39992202 | .13836689 | .74507933 | .11900350 | 5.9830060 | .03095243 | 3.5924948 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

```
  |    Y    ||    Z    ||   AA    ||   AB    ||   AC    ||   AD    ||   AE    ||   AF    ||   AG    ||   AH    ||   AI    ||   AJ    |
 1|ORGANIC CHCHEM.FERTIINSECTICIDDRUGS&PHARCOSMETICS OTHER CHEMREFACTORY CEMENT     NON METALLI&S,FERRO-I&S CASTINNON-FERROU
 2|         0         0         0         0         0         0         0         0         0         0         0         0
 3|         0         0         0         0         0         0         0         0         0         0         0         0
 4|         0         0         0         0         0         0         0         0         0         0         0         0
 5|         0         0         0         0         0         0         0         0         0         0         0         0
 6|         0         0         0         0         0         0         0         0         0         0         0         0
 7|         0         0         0         0         0         0         0         0         0         0         0         0
 8|         0 .25567979         0         0         0         0         0         0         0         0         0         0
 9| 21.895309 5.0999991         0         0         0         0         0         0         0         0         0         0
10|         0 1.7971478         0         0         0         0         0         0         0         0         0         0
11|         0 .75613950         0         0         0         0         0         0         0         0         0         0
12|         0         0         0         0         0         0         0         0         0         0         0         0
13|         0         0         0         0         0         0         0         0         0         0         0         0
14|         0         0         0         0         0         0         0         0         0         0         0         0
15|         0         0         0         0         0         0         0         0         0         0         0         0
16|         0         0         0         0         0         0         0         0         0         0         0         0
17|         0         0         0         0         0         0         0         0         0         0         0         0
18| 2.7087529 1.5027831 .06232852 .15763107 .25520969 .71044846 6.1665821 35.926815 .02677091 4.8136902 1.7488089 .94816679
19| 12.123920 4.8389355 .68895522 1.0813497 .33467408 1.6369394 2.1255523 15.661558 .29684668         0 30.256091         0
20|         0         0         0         0         0         0         0         0         0 .99815663         0         0
21|         0         0         0         0         0         0         0         0         0         0         0         0
22|         0         0         0         0         0         0         0         0         0         0         0         0
```

```
  |   AK    ||   AL    ||   AM    ||   AN    ||   AO    ||   AP    ||   AQ    ||   AR    ||   AS    ||   AT    ||   AU    ||   AV    |
 1|METAL PRODTRACTORS ENON-ELEC MELEC. MOTOELEC.CABLEOTHER ELECSHIPS&BOATRAIL EQUIPMOTOR VEHIOTHER TRANCONSTRUCTIGAS & WATE
 2|         0         0         0         0         0         0         0         0         0         0         0         0
 3|         0         0         0         0         0         0         0         0         0         0         0         0
 4|         0         0         0         0         0         0         0         0         0         0         0         0
 5|         0         0         0         0         0         0         0         0         0         0         0         0
 6|         0         0         0         0         0         0         0         0         0         0         0         0
 7|         0         0         0         0         0         0         0         0         0         0         0         0
 8|         0         0         0         0         0         0         0         0         0         0         0         0
 9|         0         0         0         0         0         0         0         0         0         0         0         0
10|         0         0         0         0         0         0         0         0         0         0         0         0
11|         0         0         0         0         0         0         0         0         0         0         0         0
12|         0         0         0         0         0         0         0         0         0         0         0         0
13|         0         0         0         0         0         0         0         0         0         0         0         0
14|         0         0         0         0         0         0         0         0         0         0         0         0
15|         0         0         0         0         0         0         0         0         0         0         0         0
16|         0         0         0         0         0         0         0         0         0         0         0         0
17|         0         0         0         0         0         0         0         0         0         0         0         0
18| .09782396 .08162042 .09564787 1.0794727 .14396318 .06793792 .23726597 .07040030 .00952665 .06616746         0         0
19| 5.2115604 2.4192788 .76094673 2.5759312 1.4184448 .68630733 1.2175854 .33396005 .18673947 .07938764         0         0
20|         0         0         0         0         0         0         0         0         0         0         0         0
21|         0         0         0         0         0         0         0         0         0         0         0         0
22|         0         0         0         0         0         0         0         0         0         0         0         0
```

```
  |   AW    ||   AX    ||   AY    |
 1|RAILWAYS  OTHER TRANSERVICES
 2|        0         0 .00144316
 3|        0         0 .00008797
 4|        0         0 .00018615
 5|        0         0 .00031024
 6|        0         0 .00471875
 7|        0         0         0
 8|        0         0         0
 9|        0         0         0
10|        0         0         0
11|        0         0         0
12|        0         0         0
13|        0 70.100525         0
14| 243.99038        0         0
15|        0 2.3109996         0
16|        0 1.7802360         0
17|        0         0         0
18|        0         0         0
19|        0         0         0
20|        0         0         0
21|        0         0         0
22|        0         0         0
```

## Table 3.5, Sub-Matrix $A_{1s}$

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | ELECTRICI | COKING COA | NON-COKING | LIGNITE | CRUDE OIL | LPG | NAPHTHA | MOGAS | ATF/JET FU | KEROSENE | HSD |
| 2 | PADDY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | WHEAT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | OTHER CEREALS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | PULSES | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | SUGARCANE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | JUTE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | COTTON | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | PLANTATION | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | MISC.FOOD PROD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | FORESTRY | .00001885 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | FISHING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | MINERALS | 0 | 0 | 0 | 0 | .00000113 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | SUGAR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | GUR&KHANSARI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | HYDROGEN OIL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | EDIBLE OIL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | COTTON TEXTILE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | OTHER TEXTILE | 0 | 0 | 0 | 0 | 0 | .00003035 | .00003128 | .00003195 | .00003228 | .00003078 | .00003227 |
| 20 | WOOD PRODUCTS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | PAPER & PRODUCT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | MISC.MANFG. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | SYNTHETICS | 0 | 0 | 0 | 0 | 0 | .00000198 | .00000204 | .00000208 | .00000211 | .00000201 | .00000210 |
| 24 | INORGANIC CHEM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | ORGANIC CHEM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | FERTILISERS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | INSECTICIDE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | DRUGS & PHARM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | COSMETICS | 0 | 0 | 0 | 0 | 0 | .00000033 | .00000034 | .00000035 | .00000035 | .00000033 | .00000035 |
| 30 | OTHER CHEM | .00003142 | .00006076 | .00006509 | .00016057 | .00047777 | .00000066 | .00000068 | .00000069 | .00000070 | .00000067 | .00000070 |
| 31 | REFRACTORY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | CEMENT | 0 | 0 | 0 | 0 | .00002769 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | OTHER NON METAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | I&S,FERROALLOY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | I&S CASTINGS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | NON-FERROUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | METAL PROD | 0 | .00004949 | .00005302 | .00013080 | .00087719 | .00003068 | .00003163 | .00003230 | .00003263 | .00003111 | .00003262 |
| 38 | TRACTORS ETC. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | NON-ELECTRIC | 0 | .00001604 | .00001719 | .00004240 | .00028336 | .00000033 | .00000034 | .00000035 | .00000035 | .00000033 | .00000035 |
| 40 | ELEC MOTORS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | ELEC CABLE | .00039595 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | OTHER ELEC MACH | .00457289 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 43 | SHIPS & BOATS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | RAIL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | MOTOR VEHICLE | 0 | 0 | 0 | 0 | 0 | .00000264 | .00000272 | .00000278 | .00000281 | .00000268 | .00000281 |
| 46 | OTHER TRANS. EQ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | CONSTRUCTION | .00033159 | .00008841 | .00009471 | .00023364 | .00009367 | .00001023 | .00001054 | .00001077 | .00001088 | .00001037 | .00001087 |
| 48 | GAS & WATER | .00021633 | .00007022 | .00005668 | .00006896 | .00002592 | .00002607 | .00002686 | .00002743 | .00002772 | .00002643 | .00002771 |
| 49 | RAILWAYS | .00807987 | .00010206 | .00010933 | .00026972 | .00004536 | .00000033 | .00000034 | .00000035 | .00000035 | .00000033 | .00000035 |
| 50 | OTHER TRANSPORT | .01026073 | .00006434 | .00006893 | .00017004 | .00009013 | .00001419 | .00001462 | .00001493 | .00001509 | .00001439 | .00001508 |
| 51 | SERVICES | .02394170 | .00000346 | .00000370 | .00000914 | .00295087 | .00027485 | .00028326 | .00028927 | .00029225 | .00027867 | .00004507 |

```
  |    M    ||    N    ||    O    ||    P    ||    Q    ||    R    ||    S    ||    T    |
 1|LDO       FUEL\OIL  OTHER PET.NATURAL GACHARCOAL  DUNG        CROP WASTEFIREWOOD
 2|         0         0         0         0         0         0         0         0
 3|         0         0         0         0         0         0         0         0
 4|         0         0         0         0         0         0         0         0
 5|         0         0         0         0         0         0         0         0
 6|         0         0         0         0         0         0         0         0
 7|         0         0         0         0         0         0         0         0
 8|         0         0         0         0         0         0         0         0
 9|         0         0         0         0         0         0         0         0
10|         0         0         0         0         0         0         0         0
11|         0         0         0         0         0         0         0         0
12|         0         0         0         0         0         0         0         0
13|         0         0         0 .00000908         0         0         0         0
14|         0         0         0         0         0         0         0         0
15|         0         0         0         0         0         0         0         0
16|         0         0         0         0         0         0         0         0
17|         0         0         0         0         0         0         0         0
18|         0         0         0         0         0         0         0         0
19| .00003060 .00003467 .00022663         0         0         0         0         0
20|         0         0         0         0         0         0         0         0
21|         0         0         0         0         0         0         0         0
22|         0         0         0         0         0         0         0         0
23| .00000200 .00000226 .00001478         0         0         0         0         0
24|         0         0         0         0         0         0         0         0
25|         0         0         0         0         0         0         0         0
26|         0         0         0         0         0         0         0         0
27|         0         0         0         0         0         0         0         0
28|         0         0         0         0         0         0         0         0
29| .00000033 .00000038 .00000246         0         0         0         0         0
30| .00000067 .00000075 .00000493 .00368373         0         0         0         0
31|         0         0         0         0         0         0         0         0
32|         0         0         0 .00021348         0         0         0         0
33|         0         0         0         0         0         0         0         0
34|         0         0         0         0         0         0         0         0
35|         0         0         0         0         0         0         0         0
36|         0         0         0         0         0         0         0         0
37| .00003093         0 .00022909 .00676334         0         0         0         0
38|         0         0         0         0         0         0         0         0
39| .00000033         0 .00000246 .00218480         0         0         0         0
40|         0         0         0         0         0         0         0         0
41|         0         0         0         0         0         0         0         0
42|         0         0         0         0         0         0         0         0
43|         0         0         0         0         0         0         0         0
44|         0         0         0         0         0         0         0         0
45| .00000266         0 .00001971         0         0         0         0         0
46|         0         0         0         0         0         0         0         0
47| .00001031         0 .00007636 .00072221         0         0         0         0
48| .00002627         0 .00019461 .00019986         0         0         0         0
49| .00000033         0 .00000246 .00034975         0         0         0         0
50| .00001430         0 .00010592 .00069496         0         0         0         0
51| .00179578         0 .00205198 .02275189         0         0         0         0
```

## Table 3.6: Sub-Matrix $A_{11}$

|  | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 |  | PADDY | WHEAT | OTHER CER | PULSES | SUGARCAN | JUTE | COTTON | PLANTANTI | MISC.FOOD | FORESTRY | FISHING |
| 2 | PADDY | .0593657 | .0001718 | 0 | 0 | 0 | 0 | 0 | 0 | .0073492 | 0 | 0 |
| 3 | WHEAT | .0000728 | .1152471 | 0 | 0 | 0 | 0 | 0 | 0 | .0118328 | 0 | 0 |
| 4 | OTHER CER | 0 | .0002918 | .0240778 | .0007979 | 0 | 0 | 0 | 0 | .0318324 | 0 | 0 |
| 5 | PULSES | .0000011 | 0 | 0 | .0762030 | 0 | 0 | 0 | 0 | .0074724 | 0 | 0 |
| 6 | SUGARCANE | 0 | 0 | 0 | 0 | .0164859 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | JUTE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | COTTON | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | PLANTATIO | .0010564 | .0006259 | 0 | .0046095 | 0 | 0 | 0 | .0184056 | .2967467 | 0 | 0 |
| 10 | MISC.FOOD | .0103577 | .0112285 | .0283952 | .1024708 | .0108930 | .0039166 | .0158565 | .0064101 | .0606614 | 0 | .0007266 |
| 11 | FORESTRY | .0000034 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0006173 | 0 | 0 |
| 12 | FISHING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0082191 | 0 | 0 |
| 13 | MINERALS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0000372 | 0 | 0 |
| 14 | SUGAR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0063665 | 0 | 0 |
| 15 | GUR&KHANS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0000592 | 0 | 0 |
| 16 | HYDROGEN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0041422 | 0 | 0 |
| 17 | EDIBLE OI | .0000022 | .0000118 | 0 | 0 | 0 | 0 | 0 | 0 | .0023956 | 0 | 0 |
| 18 | COTTON TE | 0 | 0 | 0 | 0 | 0 | 0 | .0058900 | 0 | .0111329 | 0 | 0 |
| 19 | OTHER TEX | .0002386 | .0010494 | .0000306 | .0002921 | .0000213 | 0 | .0000211 | .0000045 | .0014603 | .0061285 | 0 |
| 20 | WOOD PROD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0023894 | 0 | 0 |
| 21 | PAPER & P | .0000101 | .0000094 | .0000111 | .0000356 | .0000107 | 0 | .0000070 | .0000015 | .0033694 | 0 | 0 |
| 22 | MISC.MANF | .0000056 | .0000071 | 0 | 0 | 0 | 0 | 0 | .0000007 | .0001122 | 0 | 0 |
| 23 | SYNTHETIC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0019999 | 0 | 0 |
| 24 | INORGANIC | 0 | .0000024 | 0 | .0000356 | 0 | 0 | 0 | 0 | .0013165 | 0 | 0 |
| 25 | ORGANIC C | 0 | 0 | 0 | .0000071 | 0 | 0 | 0 | 0 | .0005567 | 0 | 0 |
| 26 | FERTILISE | .0891024 | .1238803 | .0408191 | .0358430 | .1025855 | .0295922 | .0414125 | .0604994 | .0000227 | 0 | 0 |
| 27 | INSECTICI | .0007136 | .0000541 | .0001918 | 0 | 0 | 0 | .0018274 | .0117415 | 0 | 0 | 0 |
| 28 | DRUGS & P | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0073148 | 0 | 0 |
| 29 | COSMETICS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0002512 | 0 | 0 |
| 30 | OTHER CHE | .0000022 | .0000071 | 0 | .0000285 | 0 | 0 | 0 | 0 | .0009256 | 0 | 0 |
| 31 | REFRACTOR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | CEMENT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | OTHER NON | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0006675 | 0 | 0 |
| 34 | I&S,FERRO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0001005 | 0 | 0 |
| 35 | I&S CASTI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | NON-FERRO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0000275 | 0 | 0 |
| 37 | METAL PRO | .0000728 | .0002047 | 0 | .0000499 | 0 | 0 | 0 | 0 | .0124460 | 0 | 0 |
| 38 | TRACTORS | .0003574 | .0004800 | .0024603 | .0040182 | .0004581 | .0000870 | .0008294 | .0001478 | 0 | 0 | 0 |
| 39 | NON-ELECT | .0000986 | .0004282 | 0 | .0000926 | 0 | 0 | 0 | 0 | .0025160 | .0049569 | 0 |
| 40 | ELEC MOTO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | ELEC CABL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | OTHER ELE | .0000022 | .0000047 | 0 | 0 | 0 | 0 | 0 | 0 | .0001803 | 0 | 0 |
| 43 | SHIPS & B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0006309 | .0074242 |
| 44 | RAIL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | MOTOR VEH | .0000090 | .0000494 | 0 | .0000071 | 0 | 0 | 0 | 0 | .0006971 | .0001040 | 0 |
| 46 | OTHER TRA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | CONSTRUCT | .0078775 | .0117673 | .0274833 | .0425756 | .0073081 | .0009139 | .0218870 | .0039995 | .0146922 | .0254986 | .0038437 |
| 48 | GAS & WAT | .0001557 | .0002729 | .0001612 | .0006198 | .0001278 | .0001741 | .0001617 | .0000357 | .0002677 | 0 | 0 |
| 49 | RAILWAYS | .0002588 | .0008753 | .0005477 | .0012610 | .0002131 | .0000435 | .0003374 | .0004472 | .0026206 | .0120006 | .0000948 |
| 50 | OTHER TRA | .0009847 | .0009553 | .0009007 | .0041535 | .0009055 | .0000435 | .0021718 | .0032552 | .0130144 | .0430939 | .0020956 |
| 51 | SERVICES | .0158726 | .0247182 | .0310251 | .0791097 | .0236289 | .0046564 | .0264205 | .0228553 | .1128182 | .0247152 | .1117207 |

|  | M | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MINERALS | SUGAR | GUR&KHANS | HYDROGEN | EDIBLE OI | COTTON TE | OTHER TEX | WOOD PROD | PAPER&PRO | MISC.MANF | SYNTHETIC | INORGANIC |
| 2 | 0 | 0 | .0007718 | 0 | .0016606 | .0001679 | 0 | 0 | .0001129 | .0023478 | 0 | 0 |
| 3 | 0 | 0 | .0080910 | 0 | 0 | .0000886 | .0019114 | .0000298 | .0008582 | .0013626 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | .0001283 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | .0048761 | 0 | .0000183 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | .3458760 | .5260477 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | .0296356 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | .0029175 | .2833534 | .0112174 | 0 | 0 | .0000045 | .0018846 | 0 |
| 9 | 0 | 0 | .0050141 | .3250722 | .7259441 | .0069967 | .0011474 | .0019695 | .0036136 | .0351677 | .0004111 | 0 |
| 10 | 0 | .0053910 | .0456123 | .0001165 | .0000367 | .0035450 | .0111323 | .0077089 | .0077805 | .0395139 | .0002947 | .0127493 |
| 11 | 0 | .0000121 | .0017736 | .0000083 | .0005964 | .0000327 | .0005925 | .0776632 | .0196149 | .0035007 | .0002559 | .0002739 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0028344 | .0000928 | 0 | 0 |
| 13 | 0 | .0024163 | .0000358 | 0 | 0 | .0000396 | .0000809 | .0000060 | .0017642 | .0013551 | .0045759 | .0232318 |
| 14 | 0 | .0008439 | .0321341 | 0 | 0 | 0 | 0 | 0 | .0007340 | 0 | 0 | 0 |
| 15 | 0 | .0010442 | .0256531 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | .1264867 | .0898961 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | .0000425 | .0010018 | .0603773 | .0018533 | 0 | .0000042 | 0 | 0 | .0001018 | 0 | .0005477 |
| 18 | 0 | 0 | 0 | .0083721 | .0036332 | .1021872 | .0835462 | .0002380 | .0008582 | .0014734 | .0002947 | 0 |
| 19 | 0 | .0219891 | .0007309 | .0017726 | .0008716 | .0141847 | .1335016 | .0008390 | .0231156 | .0088222 | .6286016 | .0109389 |
| 20 | 0 | .0000304 | .0001073 | .0009404 | .0004037 | .0014903 | .0021958 | .0116150 | .0075659 | .0024721 | .0010082 | .0000304 |
| 21 | 0 | .0016999 | .0000664 | .0000250 | .0000092 | .0028150 | .0012478 | .0003808 | .0869403 | .0235035 | .0536541 | .0000761 |
| 22 | 0 | .0007771 | .0000102 | .0000749 | .0000183 | .0012244 | .0009592 | .0005891 | .0000903 | .0700284 | .0007988 | .0000609 |
| 23 | 0 | 0 | 0 | .0001581 | 0 | .0032791 | .0479506 | .0217543 | .0093727 | .0630853 | .1709672 | .0015062 |
| 24 | 0 | .0014388 | .0001993 | .0091877 | .0015872 | .0093126 | .0016897 | .0016482 | .0799277 | .0098644 | .0435639 | .0260701 |
| 25 | 0 | .0000789 | .0001278 | .0003828 | .0005688 | .0006157 | .0001561 | .0004284 | .0021117 | .0022011 | .0134717 | .0025864 |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0005495 | .0035133 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0000152 |
| 28 | 0 | 0 | .0000204 | .0052263 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | .0000051 | 0 | .0003486 | .0025725 | .0005242 | .0000952 | 0 | .0003159 | .0001086 | 0 |
| 30 | .0128049 | .0005403 | .0013800 | .0014148 | .0007707 | .0123049 | .0165877 | .0096038 | .0222574 | .0213249 | .0392595 | .0065877 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | .0006314 | .0000307 | 0 | 0 | 0 | .0000307 | 0 | .0070916 | .0001857 | 0 | .0013084 |
| 33 | 0 | .0000182 | .0000102 | 0 | 0 | .0000023 | .0000767 | .0006010 | 0 | .0016501 | .0003878 | .0000152 |
| 34 | 0 | 0 | 0 | .0121670 | 0 | .0009516 | .0012938 | .0170238 | .0002936 | .0026503 | .0004033 | .0024038 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0000893 | 0 | .0004222 | 0 | 0 |
| 36 | 0 | 0 | 0 | 0 | 0 | .0001912 | .0000418 | .0000060 | 0 | .0126284 | .0009462 | .0010346 |
| 37 | .0800361 | .0231244 | .0002198 | .0819650 | .0069177 | .0057676 | .0027200 | .0186542 | .0167354 | .0117345 | .0175047 | .0194891 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | .0258582 | .0087483 | .0001278 | .0069657 | .0019441 | .0116286 | .0231751 | .0001607 | .0013551 | .0014180 | .0001474 | .0004108 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0000734 | 0 | 0 |
| 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0003728 | 0 | 0 |
| 42 | 0 | .0010988 | .0000102 | .0000749 | .0000183 | .0003452 | .0001143 | 0 | 0 | .0001183 | .0071353 | .0065420 |
| 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | 0 | .0035880 | .0000818 | .0003995 | .0000917 | .0006973 | .0002370 | .0013388 | .0025521 | .0009253 | .0005584 | .0009585 |
| 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | .0059395 | .0567819 | .0003067 | .0064164 | .0010826 | .0214286 | .0168163 | .0059622 | .0780984 | .0188498 | .0238178 | .0362397 |
| 48 | .0023261 | .0022030 | .0002044 | .0001997 | .0003119 | .0017305 | .0007096 | .0022314 | .0027553 | .0006094 | .0008144 | .0026320 |
| 49 | .0036360 | .0057735 | .0014362 | .0047103 | .0007982 | .0030412 | .0032024 | .0071523 | .0115860 | .0062873 | .0042114 | .0075461 |
| 50 | .0133469 | .0370937 | .0145107 | .0496001 | .0047341 | .0231452 | .026422 | .0399919 | .0264694 | .0227384 | .0176598 | .0180134 |
| 51 | .05 | .2938112 | .0429136 | .1964781 | .0300195 | .1606985 | .1038074 | .162556 | .1702219 | .1450174 | .1091386 | .0988757 |

|  | Y | Z | AA | AB | AC | AD | AE | AF | AG | AH | AI | AJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ORGANIC C | CHEM.FERT | INSECTICI | DRUGS&PHA | COSMETICS | OTHER CHE | REFACTORY | CEMENT | NON METAL | I&S,FERRO | I&S CASTI | NON-FERRO |
| 2 | 0 | 0 | 0 | 0 | .0115771 | 0 | .0000134 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | .0012357 | .0000114 | .0000102 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | .0000114 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | .0017162 | 0 | 0 | 0 | .0002724 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | .0117856 | .1096646 | .0015773 | .0019100 | 0 | .0010166 | 0 | 0 | 0 |
| 10 | 0 | .0014808 | .0002655 | .0124059 | .0019182 | .0043757 | .0016696 | 0 | .0009472 | .0002541 | 0 | 0 |
| 11 | 0 | .0000258 | 0 | .0124840 | .0028035 | .0070928 | .0106184 | 0 | .0038136 | 0 | .0002032 | .0011898 |
| 12 | 0 | .0000086 | 0 | 0 | 0 | 0 | 0 | 0 | .0000645 | 0 | 0 | 0 |
| 13 | .0000715 | .0527567 | .0023011 | .0005812 | .0001249 | .0017706 | .1486977 | .0566641 | .0329138 | .0250731 | .0016423 | .0083221 |
| 14 | .0005721 | 0 | 0 | .0047328 | .0000795 | .0066552 | .0000534 | 0 | 0 | 0 | .0001016 | 0 |
| 15 | 0 | 0 | 0 | .0029012 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | .0360649 | .0706316 | .0051491 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | .0000343 | 0 | .0004787 | .0205664 | .0000611 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | .0009524 | .0213268 | .0000102 | 0 | 0 | .0009373 | 0 | 0 | .0001337 |
| 19 | .0006436 | .0172293 | .0175679 | .0013529 | .0092049 | .0097284 | .0010151 | .1103673 | .0130475 | .0028599 | .0029290 | .0168582 |
| 20 | .0002145 | .0004464 | .0029649 | .0028621 | .0027581 | .0085683 | .0014291 | .0000215 | .0012051 | .0000686 | .0002032 | .0036096 |
| 21 | 0 | .0000773 | .0023896 | .0118393 | .0088758 | .0079883 | .0079204 | .0013517 | .0024002 | .0005002 | .0004063 | .0025601 |
| 22 | .0015017 | .0033008 | .0002655 | .0019732 | .0023608 | .0007530 | .0000935 | .0001287 | .0033970 | .0001250 | .0001693 | .0035027 |
| 23 | 0 | .0152291 | .0161519 | .0042688 | .0006016 | .0188055 | .0046080 | 0 | .0056584 | .0012585 | .0008296 | .0022861 |
| 24 | .0095824 | .0477777 | .0487654 | .0116879 | .0373418 | .0634992 | .0026579 | .0002360 | .0213392 | .0010407 | .0029798 | .0135627 |
| 25 | .0505578 | .0029102 | .0261970 | .0548788 | .0052551 | .0433402 | .0001736 | .0000215 | .0006546 | .0001492 | .0002878 | .0007687 |
| 26 | 0 | .1348986 | .0007965 | 0 | 0 | .0020047 | 0 | .0102128 | 0 | 0 | 0 | 0 |
| 27 | 0 | .0002618 | .1414284 | 0 | 0 | .0000204 | 0 | 0 | .0006596 | 0 | 0 | 0 |
| 28 | 0 | 0 | .0000885 | .2153686 | .0006356 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | .0011718 | .0007080 | .0064423 | .1357131 | .0119366 | .0003606 | 0 | .0015225 | 0 | 0 | .0002273 |
| 30 | .0050057 | .0069235 | .1133729 | .0134218 | .0235287 | .0660127 | .0022973 | .0000858 | .0057228 | .0006938 | .0022010 | .0134491 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | .0070255 | 0 | .0000793 | .0083577 | .0010666 | 0 |
| 32 | 0 | .0000558 | 0 | 0 | 0 | .0001018 | .0004274 | .0043555 | .0307020 | 0 | 0 | 0 |
| 33 | 0 | .0000043 | 0 | .0192193 | .0042449 | .0014959 | .0000267 | 0 | .0606750 | 0 | 0 | .0005882 |
| 34 | 0 | .0000172 | .0133198 | 0 | .0000568 | .0078662 | .0061306 | .0044842 | .0220830 | .0904463 | .1466012 | .2477925 |
| 35 | 0 | .0000172 | 0 | 0 | .0000227 | 0 | .0000401 | .0136243 | .0051079 | .0143356 | .0523152 | .0043516 |
| 36 | 0 | .0000429 | .0003540 | .0013725 | .0030305 | .0423430 | .0067450 | 0 | .0000446 | .0633403 | .0352493 | .1498386 |
| 37 | .0122998 | .0115892 | .0604921 | .0137685 | .0380455 | .0491813 | 0 | .0083462 | .0153337 | .0129480 | .0147295 | .0479409 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | .0000715 | .0054555 | .0003540 | 0 | .0002270 | .0002646 | 0 | 0 | .0012844 | 0 | 0 | .0010428 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .0000050 | 0 | 0 | .0000067 |
| 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | .0053633 | .0036914 | .0128330 | .0000391 | 0 | .0060141 | 0 | 0 | 0 | 0 | 0 | .0003075 |
| 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | .0008581 | .0017470 | .0012390 | .0006008 | .0002497 | .0018419 | .0027648 | .0067370 | .0022267 | .0032148 | .0013036 | .0015107 |
| 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | .0519880 | .0316429 | .0212408 | .0236493 | .0071165 | .0322380 | .0285161 | .0106634 | .0301813 | .1390920 | .0431220 | .0149197 |
| 48 | .0010011 | .0047773 | .0007523 | .0008645 | .0002951 | .0008650 | .0006144 | .0063079 | .0009125 | .0021056 | .0009820 | .0010227 |
| 49 | .0010727 | .0074686 | .0032304 | .0022125 | .0033142 | .0039382 | .0328570 | .0401433 | .0138955 | .0267551 | .0028274 | .0046524 |
| 50 | .0075801 | .0281232 | .0661563 | .029227 | .0538215 | .0400533 | .0286363 | .0221207 | .0372481 | .0365569 | .0426987 | .0750396 |
| 51 | .0550629 | .1481618 | .1671387 | .174796 | .1673666 | .1601217 | .1764792 | .1221893 | .1877480 | .1644072 | .1425548 | .2368768 |

|  | AK | AL | AM | AN | AO | AP | AQ | AR | AS | AT | AU | AV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | METAL PROD | TRACTORS E | NON-ELEC M | ELEC. MOTO | ELEC.CABLE | OTHER ELEC | SHIPS&BOAT | RAIL EQUIP | MOTOR VEHI | OTHER TRAN | CONSTRUCTI | GAS &.WATE |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | .00004328 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | .00003185 | 0 | 0 | .00017312 | .00007429 | 0 | 0 | 0 | 0 | 0 |
| 11 | .00001930 | .00011354 | .00068788 | .00003367 | 0 | .00031161 | .00468053 | .00266870 | .00030173 | .00043881 | .01971584 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | .00007108 | .00064919 | 0 | 0 | 0 | 0 | .01734145 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | .00000866 | 0 | 0 | 0 | .00001416 | 0 | 0 |
| 18 | 0 | 0 | .00032483 | 0 | .00132683 | .00045876 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | .00003088 | .00018166 | .00065922 | 0 | .00511776 | .00021640 | .00653789 | .00234846 | .03906476 | .02345530 | 0 | .00048636 |
| 20 | .00007333 | .00043145 | .00185665 | .00222245 | .00445434 | .00779025 | .00066865 | .00015250 | .00097908 | .00159955 | .05783092 | 0 |
| 21 | .00000386 | .00002271 | .00132481 | .00006735 | .00428849 | .00377394 | 0 | .00004575 | .00025247 | .00050959 | 0 | .00004421 |
| 22 | .00169041 | .00994596 | .00321967 | .00161632 | .00691845 | .00486458 | .00646360 | .00282120 | .05146031 | .01677401 | .00009122 | .00422985 |
| 23 | 0 | 0 | .00202543 | .00400714 | .07610292 | .01025716 | 0 | 0 | .00246310 | .00042466 | 0 | 0 |
| 24 | .00002702 | .00015895 | .00125793 | .00090918 | .00303274 | .00616295 | .00222883 | .00109798 | .01437219 | .00254795 | 0 | 0 |
| 25 | .00000386 | .00002271 | .00022611 | .00020204 | .00156376 | .00444910 | .00230312 | .00056424 | .00204437 | .00025480 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | .00000637 | .00026939 | .00007108 | .00016446 | 0 | 0 | .01275270 | .00125982 | 0 | 0 |
| 30 | .00023928 | .00140788 | .00502537 | .00693673 | .01078046 | .00650919 | .00215453 | .00643538 | .01466160 | .00629910 | .00892693 | .00359611 |
| 31 | .00000386 | .00002271 | .00017516 | 0 | 0 | .00007790 | 0 | 0 | 0 | 0 | .04647720 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | .00003462 | 0 | 0 | 0 | 0 | .02947671 | 0 |
| 33 | 0 | 0 | .00017197 | .00292959 | .00137421 | .01550260 | .00007429 | .00001525 | .00030173 | .00002831 | .06457690 | 0 |
| 34 | .00786931 | .04630092 | .02688475 | .07290299 | .05847510 | .02908361 | .05334324 | .08635913 | .03686029 | .03146720 | .09925074 | 0 |
| 35 | .00402535 | .02368409 | .05620257 | .00989999 | .00002369 | .00212934 | .00126300 | .00215021 | .04765482 | .01818954 | 0 | 0 |
| 36 | .00059821 | .00351969 | .18224434 | .11196417 | .35253282 | .08042137 | .01151560 | .04983607 | .02796850 | .01627858 | .00034807 | 0 |
| 37 | .00233493 | .01373814 | .02397399 | .04710914 | .00369616 | .01598733 | .05349183 | .11948151 | .03460039 | .06375540 | .00198168 | 0 |
| 38 | .02630949 | .15479813 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | .00448848 | .02640901 | .09183235 | .18086002 | .00040279 | .01352907 | .05156018 | .00654213 | .04744546 | .09266049 | 0 | .03083225 |
| 40 | .00001930 | .00011354 | .00884057 | .01185305 | 0 | .00098677 | 0 | .00962257 | .00192122 | 0 | 0 | 0 |
| 41 | .00004631 | .00027249 | .00130889 | .05640300 | .00196655 | .03029542 | .00304606 | .00126573 | 0 | .00045297 | .00008022 | 0 |
| 42 | .00004631 | .00027249 | .00003503 | .06445095 | 0 | .09646063 | .01582467 | .00295844 | .01347931 | 0 | 0 | 0 |
| 43 | 0 | 0 | 0 | 0 | 0 | 0 | .02369985 | 0 | 0 | 0 | 0 | 0 |
| 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .13842165 | 0 | 0 | 0 | 0 |
| 45 | .00213425 | .01255734 | .00094265 | .00026939 | .00087665 | .00187832 | .00074294 | .00195196 | .03138605 | .00108996 | 0 | .00028003 |
| 46 | 0 | 0 | .00001911 | 0 | 0 | 0 | 0 | 0 | 0 | .13587657 | 0 | 0 |
| 47 | .00103432 | .00608565 | .01633403 | .01488366 | .00950102 | .01573631 | .08246657 | .02019062 | .02764829 | .00866303 | 0 | .01392757 |
| 48 | .00002702 | .00015895 | .00075794 | .00040408 | .00061603 | .00054532 | .00037147 | .00109798 | .00082514 | .00052375 | .00041730 | .07489937 |
| 49 | .00016981 | .00099914 | .00140124 | .00151530 | .00217978 | .00215530 | .00148588 | .00283645 | .00247542 | .00152877 | .00662241 | .01809847 |
| 50 | .00314927 | .01852945 | .01588500 | .02528875 | .03392883 | .02376027 | .02511144 | .04073199 | .02693400 | .02109137 | .05046708 | .01464974 |
| 51 | .01160520 | .06828194 | .08604585 | .11607233 | .18663223 | .13095413 | .10676077 | .12980557 | .22783672 | .09750159 | .24187257 | .06458265 |

```
   |    AW    ||    AX    ||    AY    |
  1|RAILWAYS  OTHER TRANSERVICES
  2|        0          0 .00503231
  3|        0          0 .00312108
  4|        0          0 .00005330
  5|        0          0 .00039610
  6|        0          0         0
  7|        0          0         0
  8|        0          0         0
  9|        0          0 .00172292
 10|        0  .02025565 .00334153
 11| .00000507 .00000123 .00000083
 12|        0          0 .00055827
 13|        0          0 .00035234
 14|        0          0 .00007984
 15|        0          0         0
 16|        0          0         0
 17|        0          0         0
 18|        0          0 .00000062
 19| .01152843 .00650219 .00099232
 20| .00006078 .00005060 .00247115
 21| .00042548 .00123775 .00825459
 22| .00045080 .05612075 .03529936
 23|        0          0 .00101492
 24|        0          0 .00003878
 25|        0          0 .00000373
 26|        0          0         0
 27|        0          0 .00003961
 28|        0  .00000740 .03064552
 29|        0          0 .00000850
 30|        0          0 .00005807
 31|        0          0         0
 32|        0          0         0
 33|        0          0 .00005019
 34| .00046600 .00294814 .00238530
 35|        0          0         0
 36|        0          0 .00006657
 37|        0  .00000494 .00534359
 38|        0          0 .00001431
 39|        0  .00750054 .00150911
 40|        0          0         0
 41| .00432063          0 .00021381
 42| .01771306 .00054668 .00052405
 43| .00026846 .00894684         0
 44| .07248322          0         0
 45|        0  .03116462 .00099170
 46|        0  .02115527 .00007839
 47| .10217551 .00183503 .02381377
 48| .00097759 .00029247 .00109103
 49| .01355958 .00243231 .00573595
 50| .01067241 .01350664 .03749677
 51| .03410409 .14607906 .11687953
```

```
..TITLE
  (83TITLE)
     Title: TEESE TRIAL17

..OBJECTIVE
  (83VARIABLE)
  (83COST)
     Objective: MINIMIZED Variables:    183
          0.0000 ST.LIGHT
          0.0000 FWW
          0.0000 74
          0.0000 75.0000
          0.0000 76.0000
          0.0000 77.0000
          0.0000 78.0000
          0.0000 79.0000
          0.0000 80.0000
          0.0000 81.0000
          0.0000 FFS
          0.0000 83
          0.0000 RMF
          0.0000 WMF
          0.0000 AMF
          0.0000 RAMF
          0.0000 88
          0.0000 89.0000
          0.0000 ORE
          0.0000 NGFS
          0.0000 CFS
          0.0000 93
          0.0000 94.0000
          0.0000 EFS
          0.0000 ED
          0.0000 97
          0.0000 98.0000
          0.0000 99.0000
          0.0000 FH
          0.0000 101
          0.0000 NFS
          0.0000 103
          0.0000 104.0000
          0.0000 105.0000
          0.0000 106.0000
          0.0000 107.0000
          0.0000 IRRI
          0.0000 109
          0.1000 DCO
          0.0000 LIGHTING
          0.0000 HEATING
          0.0000 COOLING
          0.0000 114
          0.0000 115.0000
          0.0000 116.0000
          0.0000 117.0000
          0.0000 118.0000
          0.0000 119.0000
          0.0000 120.0000
          0.0000 121.0000
          0.0000 122.0000
          0.0000 123.0000
          0.0000 124.0000
          0.0000 125.0000
          0.0000 126.0000
          0.0000 127.0000
          0.0000 128.0000
          0.0000 129.0000
          0.0000 130.0000
          0.0000 131.0000
          0.0000 132.0000
          0.0000 133.0000
          0.0000 134.0000
          0.0000 135.0000
          0.0000 136.0000
          0.0000 137.0000
          0.0000 138.0000
          0.0000 139.0000
          0.0000 140.0000
          0.0000 141.0000
          0.0000 142.0000
          0.0000 143.0000
          0.0000 144.0000
          0.0000 145.0000
          0.0000 146.0000
          0.0000 147.0000
          0.0000 148.0000
          0.0000 149.0000
          0.0000 150.0000
          0.0000 151.0000
          0.0000 152.0000
          0.0000 153.0000
          0.0000 154.0000
          0.0000 155.0000
          0.0000 156.0000
          0.0000 157.0000
          2.0300 DELEC
          0.7500 GELEC
          0.6400 TELEC
          0.6700 NELEC
          0.4700 HELEC
          0.0000 163
          0.0000 164.0000
```

```
0.0000 165.0000
0.0000 166.0000
0.0000 MS
0.0000 168
0.0000 169.0000
0.0000 170.0000
0.0000 171.0000
0.0000 172.0000
0.0000 173.0000
0.0000 174.0000
0.0200 CHAR
0.1400 DUNG
0.1100 CW
0.1070 FW
0.0000 179
0.0000 180.0000
0.0000 181.0000
0.0300 COAL
0.0000 183
0.2400 NAT.GAS
0.0200 HSD
0.0600 ATF
0.0800 NAPH
0.0200 FO
0.0000 OPF
0.0100 LDO
0.0100 SKO
0.0300 LPG
0.2200 IHSD
0.2100 IMS
0.2300 IATF
0.2100 INAPH
0.1500 IFO
0.1200 ICO
0.2100 ILDO
0.2300 ISKO
0.2100 ILPG
0.0000 202
0.0000 203
0.0000 INORGANI
0.0000 MINERALS
0.0000 SUGAR
0.0000 GUR
0.0000 HYD.OIL
0.0000 EDIBLE O
```

```
0.0000 COTTON T
0.0000 TEXT OTH
0.0000 WOOD
0.0000 PAPER
0.0000 MANFG MI
0.0000 SYNTHETI
0.0000 ORGANIC
0.0000 FERTILIZ
0.0000 INSECTIC
0.0000 SRUGS
0.0000 COSMETIC
0.0000 CHEMICAL
0.0000 REFRACTO
0.0000 CEMENT
0.0000 NONMETAL
0.0000 I&S
0.0000 I/SCASTI
0.0000 NON-FERR
0.0000 METAL PR
0.0000 TRACTORS
0.0000 NONELEC
0.0000 MOTORS
0.0000 CABLES
0.0000 ELECMACH
0.0000 SHIPS
0.0000 RAILEQPM
0.0000 VEHICLES
0.0000 OTHER TR
0.0000 CONSTRUC
0.0000 GAS/WATE
0.0000 RAILWAYS
0.0000 TRANSOTH
0.0000 SERVICES
0.0000 PADDY
0.0000 WHEAT
0.0000 CEREALS
0.0000 PULSES
0.0000 SUGARCAN
0.0000 JUTE
0.0000 COTTON
0.0000 PLANTATI
0.0000 FOOD MIS
0.0000 FORESTRY
0.0000 FISHING
0.0000 FINALDEM
```

```
..BOUNDS
  (83LOWER)
  (83UPPER)
     Lower & Upper Bounds
              0.0000 <= DCO           <= 150000.0000
              0.0000 <= DELEC         <=    800.0000
              0.0000 <= GELEC         <=    750.0000
              0.0000 <= TELEC         <= 60,000.0000
              0.0000 <= NELEC         <=  5,000.0000
              0.0000 <= HELEC         <= 50,000.0000
              0.0000 <= MS            <= 17.000.0000
              0.0000 <= CHAR          <=  5,000.0000
              0.0000 <= DUNG          <= 153000.0000
              0.0000 <= CW            <= 110000.0000
              0.0000 <= FW            <= 450000.0000
              0.0000 <= COAL          <= 650000.0000
              0.0000 <= NAT.GAS       <= 23.000.0000
              0.0000 <= HSD           <= 90,000.0000
              0.0000 <= ATF           <= 12,500.0000
              0.0000 <= NAPH          <= 28,000.0000
              0.0000 <= FO            <= 67,000.0000
              0.0000 <= LDO           <= 13,500.0000
              0.0000 <= SKO           <= 28.000.0000
              0.0000 <= LPG           <=  5.000.0000
         6,000.0000 <= INORGANI      <=  6.000.0000
         4.428.0000 <= MINERALS      <=  4.428.0000
        16.471.0000 <= SUGAR          = 16.471.0000
        19.564.0000 <= GUR            = 19.564.0000
        12,016.0000 <= HYD.OIL       <= 12.016.0000
        10.899.0000 <= EDIBLE O      <= 10.899.0000
        42,877.0000 <= COTTON T      <= 42.877.0000
        65.000.0000 <= TEXT OTH      <= 65,000.0000
        15.000.0000 <= WOOD           = 15,000.0000
         8.000.0000 <= PAPER         <=  8,000.0000
        60.000.0000 <= MANFG MI       = 60.000.0000
        12.000.0000 <= SYNTHETI       = 12.000.0000
         1.300.0000 <= ORGANIC       <=  1,300.0000
        20.000.0000 <= FERTILIZ       = 20.000.0000
         2.000.0000 <= INSECTIC      <=  2.000.0000
        18.000.0000 <= DRUGS         <= 18.000.0000
         8.000.0000 <= COSMETIC      <=  8.000.0000
         9.000.0000 <= CHEMICAL      <=  9,000.0000
         7.000.0000 <= REFRACTO       =  7.000.0000
        400000.0000 <= CEMENT         = 400000.0000
        18.000.0000 <= NONMETAL       = 18.000.0000
        20.000.0000 <= I&S           <= 20,000.0000
         5.000.0000 <= I/SCASTI      <=  5.000.0000
        13.500.0000 <= NON-FERR      <= 13.500.0000
        25.000.0000 <= METAL FR      <= 25.000.0000
         4,000.0000 <= TRACTORS      <=  4,000.0000
        30.000.0000 <= NONELEC       <= 30.000.0000
         2.500.0000 <= MOTORS        <=  2,500.0000
         4.000.0000 <= CABLES        <=  4,000.0000
        10.000.0000 <= ELECMACH      <= 10.000.0000
```

```
   1,300.0000 <= SHIPS      <=   1,300.0000
   6,500.0000 <= RAILEQPM   <=   6,500.0000
  15,000.0000 <= VEHICLES   <=  15,000.0000
   7,000.0000 <= OTHER TR   <=   7,000.0000
  140000.0000 <= CONSTRUC   <=  140000.0000
   6,785.0000 <= GAS/WATE   <=   6,785.0000
  19,742.0000 <= RAILWAYS   <=  19,742.0000
  70,000.0000 <= TRANSOTH   <=  70,000.0000
  350000.0000 <= SERVICES   <=  350000.0000
  89,267.0000 <= PADDY      <=  89,267.0000
  42,499.0000 <= WHEAT      <=  42,499.0000
  35,970.0000 <= CEREALS    <=  35,970.0000
  14,036.0000 <= PULSES     <=  14,036.0000
  18,773.0000 <= SUGARCAN   <=  18,773.0000
   2,297.0000 <= JUTE       <=   2,297.0000
  14,227.0000 <= COTTON     <=  14,227.0000
  134616.0000 <= PLANTATI   <=  134616.0000
  145308.0000 <= FOOD MIS   <=  145308.0000
  14,425.0000 <= FORESTRY   <=  14,425.0000
   9,496.0000 <= FISHING    <=   9,496.0000
  212000.0000 <= FINALDEM   <=  212000.0000

..CONSTRAINTS
  (83CONSTRAINT)
    Row: LIGHTING Elements:    3
            -1.0000 LIGHTING
             0.1443 SERVICES
             0.5660 FINALDEM =          0.0000

    Row: COOKING  Elements:    3
            -1.0000 COOKING
             0.0100 SERVICES
             0.3070 FINALDEM =          0.0000

    Row: HEATING  Elements:    3
            -1.0000 HEATING
             0.0186 SERVICES
             0.0710 FINALDEM =          0.0000

    Row: ST.LIGHT Elements:    2
            -1.0000 ST.LIGHT
             0.0310 SERVICES =          0.0000

    Row: FWW      Elements:    2
            -1.0000 FWW
             0.4718 SERVICES =          0.0000

    Row: EFS      Elements:    3
            -1.0000 EFS
             2.8441 INORGANI
             0.9965 NON-FERR =          0.0000

    Row: CFS      Elements:    2
            -1.0000 CFS
             0.2557 FERTILIZ =          0.0000

    Row: NFS      Elements:    3
            -1.0000 NFS
            21.8953 ORGANIC
             5.1000 FERTILIZ =          0.0000
```

```
Row: FFS          Elements:    2
       -1.0000 FFS
        1.7971 FERTILIZ =            0.0000

Row: NGFS         Elements:    2
       -1.0000 NGFS
        0.7561 FERTILIZ =            0.0000

Row: RMP          Elements:    3
       -1.0000 RMP
        0.7010 TRANSOTH
        0.0560 FINALDEM =            0.0000

Row: RAMP         Elements:    2
       -1.0000 RAMP
        2.4400 RAILWAYS =            0.0000

Row: AMP          Elements:    2
       -1.0000 AMP
        0.0231 TRANSOTH =            0.0000

Row: WMP          Elements:    2
       -1.0000 WMP
        0.0178 TRANSOTH =            0.0000

Row: FH           Elements:   35
       -1.0000 FH
        2.2955 INORGANI
        0.3984 SUGAR
        0.0098 GUR
        0.6981 HYD.OIL
        0.2062 EDIBLE O
        1.8756 COTTON T
        0.4053 TEXT OTH
        0.0642 WOOD
        7.2458 PAPER
        0.0113 MANFG MI
        2.1613 SYNTHETI
        2.7088 ORGANIC
        1.5028 FERTILIZ
        0.0623 INSECTIC
        0.1576 SRUGS
        0.2552 COSMETIC
        0.7104 CHEMICAL
        6.1666 REFRACTO
        0.3593 CEMENT
        0.0268 NONMETAL
        4.8137 I&S
        1.7488 I/SCASTI
        0.9482 NON-FERR
        0.0978 METAL FR
        0.0816 TRACTORS
        0.0956 NONELEC
        1.0795 MOTORS
        0.1440 CABLES
        0.0679 ELECMACH
        0.2373 SHIPS
        0.0704 RAILEQPM
        0.0095 VEHICLES
        0.0662 OTHER TR
        0.1484 FOOD MIS =            0.0000
```

```
Row: ED           Elements:   32
       -1.0000 ED
        0.5258 SUGAR
        0.0024 GUR
        0.6535 HYD.OIL
        0.3999 EDIBLE O
        0.1384 COTTON T
        0.7451 TEXT OTH
        0.1190 WOOD
        5.9830 PAPER
        0.0310 MANFG MI
        3.5925 SYNTHETI
       12.1239 ORGANIC
        4.8389 FERTILIZ
        0.6890 INSECTIC
        1.0814 SRUGS
        0.3847 COSMETIC
        1.6369 CHEMICAL
        2.1256 REFRACTO
        0.1566 CEMENT
        0.2968 NONMETAL
       30.2561 I/SCASTI
        5.2116 METAL PR
        2.4193 TRACTORS
        0.7609 NONELEC
        2.5759 MOTORS
        1.4184 CABLES
        0.6863 ELECMACH
        1.2176 SHIPS
        0.3340 RAILEQPM
        0.1867 VEHICLES
        0.0794 OTHER TR
        0.1601 FOOD MIS =          0.0000

Row: OR           Elements:    2
       -1.0000 ORE
        0.9982 I&S      =          0.0000

Row: IRRI         Elements:    9
       -1.0000 IRRI
        0.2144 PADDY
        0.2144 WHEAT
        0.2144 CEREALS
        0.2144 PULSES
        0.2144 SUGARCAN
        0.2144 JUTE
        0.2144 COTTON
        0.2144 PLANTATI =          0.0000

Row: 114          Elements:    2
        0.1843 EFS
       -1.0000 114      =          0.0000

Row: 115.0000 Elements:    2
        0.0451 ED
       -1.0000 115.0000 =          0.0000

Row: 116.0000 Elements:    2
        0.0420 RAMP
       -1.0000 116.0000 =          0.0000

Row: 117.0000 Elements:    2
        0.1534 IRRI
       -1.0000 117.0000 =          0.0000
```

```
Row:  118.0000 Elements:     6
           0.0409 ST.LIGHT
           0.0053 PWW
           0.0444 LIGHTING
           0.1108 HEATING
           0.0016 COOKING
          -1.0000 118.0000 =           0.0000

Row:  119.0000 Elements:     2
           0.1840 CFS
          -1.0000 119.0000 =           0.0000

Row:  120.0000 Elements:     2
           1.1800 RAMF
          -1.0000 120.0000 =           0.0000

Row:  121.0000 Elements:     2
           0.2231 FH
          -1.0000 121.0000 =           0.0000

Row:  122.0000 Elements:     2
           7.1300 WMF
          -1.0000 122.0000 =           0.0000

Row:  123.0000 Elements:     2
           5.3345 ORE
          -1.0000 123.0000 =           0.0000

Row:  124.0000 Elements:     2
           0.0068 HEATING
          -1.0000 124.0000 =           0.0000

Row:  125.0000 Elements:     2
           0.1842 NGFS
          -1.0000 125.0000 =           0.0000

Row:  126.0000 Elements:     2
           0.2000 RAMF
          -1.0000 126.0000 =           0.0000

Row:  127.0000 Elements:     2
           1.2200 RMF
          -1.0000 127.0000 =           0.0000

Row:  128.0000 Elements:     2
           0.1840 IRRI
          -1.0000 128.0000 =           0.0000

Row:  129.0000 Elements:     2
           0.4500 WMF
          -1.0000 129.0000 =           0.0000

Row:  130.0000 Elements:     2
           0.2400 RMF
          -1.0000 130.0000 =           0.0000

Row:  131.0000 Elements:     2
           6.7500 AMF
          -1.0000 131.0000 =           0.0000

Row:  132.0000 Elements:     2
           0.1841 NFS
          -1.0000 132.0000 =           0.0000
```

```
Row:  133.0000 Elements:     2
          0.0199 IRRI
        -1.0000 133.0000 =             0.0000

Row:  134.0000 Elements:     2
          0.0569 FH
        -1.0000 134.0000 =             0.0000

Row:  135.0000 Elements:     2
          1.8900 WMF
        -1.0000 135.0000 =             0.0000

Row:  136.0000 Elements:     2
          0.1875 FFS
        -1.0000 136.0000 =             0.0000

Row:  137.0000 Elements:     2
          0.6856 WMF
        -1.0000 137.0000 =             0.0000

Row:  138.0000 Elements:     2
          0.1572 IRRI
        -1.0000 138.0000 =             0.0000

Row:  139.0000 Elements:     2
          0.1359 LIGHTING
        -1.0000 139.0000 =             0.0000

Row:  140.0000 Elements:     2
          0.1188 HEATING
        -1.0000 140.0000 =             0.0000

Row:  141.0000 Elements:     2
          0.1996 COOLING
        -1.0000 141.0000 =             0.0000

Row:  142.0000 Elements:     2
          0.0034 HEATING
        -1.0000 142.0000 =             0.0000

Row:  143.0000 Elements:     2
          0.0682 COOLING
        -1.0000 143.0000 =             0.0000

Row:  144.0000 Elements:     2
          0.0269 HEATING
        -1.0000 144.0000 =             0.0000

Row:  145.0000 Elements:     2
          0.0506 COOLING
        -1.0000 145.0000 =             0.0000

Row:  146.0000 Elements:     2
          0.2394 HEATING
        -1.0000 146.0000 =             0.0000

Row:  147.0000 Elements:     2
          2.1156 COOLING
        -1.0000 147.0000 =             0.0000

Row:  148.0000 Elements:     2
          0.2908 HEATING
        -1.0000 148.0000 =             0.0000
```

```
Row:  149.0000 Elements:     2
          1.4410 COOKING
         -1.0000 149.0000 =          0.0000

Row:  150.0000 Elements:     2
          0.7633 HEATING
         -1.0000 150.0000 =          0.0000

Row:  151.0000 Elements:     2
          0.0432 COOKING
         -1.0000 151.0000 =          0.0000

Row:  152.0000 Elements:     2
          6.2170 COOKING
         -1.0000 152.0000 =          0.0000

Row:  153.0000 Elements:    10
         -1.0000 114
         -1.0000 115.0000
         -1.0000 116.0000
         -1.0000 117.0000
         -1.0000 118.0000
          1.0000 153.0000
          1.0000 154.0000
          1.0000 155.0000
          1.0000 156.0000
          1.0000 157.0000 =          0.0000

Row:  158      Elements:     2
          1.0526 157.0000
         -1.0000 DELEC    =          0.0000

Row:  159      Elements:     2
          1.2500 156.0000
         -1.0000 GELEC    =          0.0000

Row:  160.0000 Elements:     2
          1.4620 155.0000
         -1.0000 TELEC    =          0.0000

Row:  161.0000 Elements:     2
          1.2500 154.0000
         -1.0000 NELEC     <=        0.0000

Row:  162.0000 Elements:     2
          1.2500 153.0000
         -1.0000 HELEC     <=        0.0000

Row:  163.0000 Elements:     2
          2.8571 TELEC
         -1.0000 163      =          0.0000

Row:  164.0000 Elements:     5
          1.0000 119.0000
          1.0000 120.0000
          1.0000 121.0000
          1.0000 122.0000
         -1.0000 164.0000 =          0.0000
```

```
Row:  165.0000 Elements:    4
          1.0000 123.0000
          1.0000 124.0000
          1.0000 151.0000
         -1.0000 165.0000  =          0.0000

Row:  166.0000 Elements:    2
         5.8824 GELEC
        -1.0000 166.0000  =          0.0000

Row:  167.0000 Elements:    2
        -1.0000 MS
         0.0583 203       =          0.0000

Row:  168.0000 Elements:    2
         2.6316 DELEC
        -1.0000 168       =          0.0000

Row:  169.0000 Elements:    6
          1.0000 126.0000
          1.0000 127.0000
          1.0000 128.0000
          1.0000 129.0000
          1.0000 168
         -1.0000 169.0000  =          0.0000

Row:  170.0000 Elements:    2
          1.0309 132.0000
         -1.0000 170.0000  =          0.0000

Row:  171.0000 Elements:    5
          1.0000 133.0000
          1.0000 134.0000
          1.0000 135.0000
          1.0000 136.0000
         -1.0000 171.0000  =          0.0000

Row:  172.0000 Elements:    3
          1.0000 137.0000
          1.0000 138.0000
         -1.0000 172.0000  =          0.0000

Row:  173.0000 Elements:    4
          1.0000 139.0000
          1.0000 140.0000
          1.0000 141.0000
         -1.0000 173.0000  =          0.0000

Row:  174.0000 Elements:    3
          1.0000 142.0000
          1.0000 143.0000
         -1.0000 174.0000  =          0.0000

Row:  175.0000 Elements:    3
          1.0000 144.0000
          1.0000 145.0000
         -1.0000 CHAR      =          0.0000

Row:  176.0000 Elements:    3
          1.0000 146.0000
          1.0000 147.0000
         -1.0000 DUNG     <=          0.0000
```

```
Row:  177.0000 Elements:    3
          1.0000 148.0000
          1.0000 149.0000
         -1.0000 CW            <=        0.0000

Row:  178.0000 Elements:    3
          1.0000 150.0000
          1.0000 152.0000
         -1.0000 FW            <=        0.0000

Row:  179.0000 Elements:    3
          1.0000 163
          1.0000 164.0000
         -1.0000 179          =          0.0000

Row:  180.0000 Elements:    2
          1.0820 179
         -1.0000 130.0000 =              0.0000

Row:  181.0000 Elements:    2
          1.2500 165.0000
         -1.0000 181.0000 =              0.0000

Row:  182.0000 Elements:    3
          1.0000 180.0000
          1.0000 181.0000
         -1.0000 COAL          <=        0.0000

Row:  183.0000 Elements:    3
          1.0000 125.0000
          1.0000 166.0000
         -1.0000 183          =          0.0000

Row:  184.0000 Elements:    2
         3.7037 183
        -1.0000 NAT.GAS       =          0.0000

Row:  185.0000 Elements:    2
        -1.0000 HSD
         0.2993 203           =          0.0000

Row:  186.0000 Elements:    2
        -1.0000 ATF
         0.0422 203           =          0.0000

Row:  187          Elements:    2
        -1.0000 NAPH
         0.0953 203           =          0.0000

Row:  188.0000 Elements:    2
        -1.0000 FO
         0.2287 203           =          0.0000

Row:  190          Elements:    2
        -1.0000 LDO
         0.0458 203           =          0.0000

Row:  191.0000 Elements:    2
        -1.0000 SKO
         0.0970 203           =          0.0000

Row:  192.0000 Elements:    2
        -1.0000 LPG
         0.0160 203           =          0.0000
```

```
Row:  193.0000 Elements:    3
           1.0000 169.0000
          -1.0000 HSD
          -1.0000 IHSD         <=         0.0000

Row:  194.0000 Elements:    3
           1.0000 130.0000
          -1.0000 MS
          -1.0000 IMS          <=         0.0000

Row:  195.0000 Elements:    3
           1.0000 131.0000
          -1.0000 ATF
          -1.0000 IATF         <=         0.0000

Row:  196.0000 Elements:    3
           1.0000 170.0000
          -1.0000 NAPH
          -1.0000 INAPH        <=         0.0000

Row:  197.0000 Elements:    3
           1.0000 171.0000
          -1.0000 FO
          -1.0000 IFO          <=         0.0000

Row:  199          Elements:    3
           1.0000 172.0000
          -1.0000 LDO
          -1.0000 ILDO         <=         0.0000

Row:  200.0000 Elements:    3
           1.0000 173.0000
          -1.0000 SHO
          -1.0000 ISHO         <=         0.0000

Row:  201.0000 Elements:    3
           1.0000 174.0000
          -1.0000 LFG
          -1.0000 ILFG         <=         0.0000

Row:  2.021        Elements:   10
           1.0000 MS
           1.0000 HSD
           1.0000 ATF
           1.0000 NAPH
           1.0000 FO
           1.0000 OFF
           1.0000 LDO
           1.0000 SHO
           1.0000 LFG
          -1.0000 202         =          0.0000

Row:  202          Elements:    2
          -1.0000 202
           0.8826 203         =          0.0000

Row:  203          Elements:    3
           1.0000 DCO
           1.0000 ICO
          -1.0000 203         >=         0.0000
```

```
..ACTIVITY
  (83VA)
  (83CA)
..REDUCEDCOS
  (83VR)
  (83CR)

Statistics-
  LP63 Version 5.00
  Machine memory:  512K bytes.
  Pagable memory:  302K bytes.
  Variables:       183
  Constraints:     103
    15 LE,  87 EQ.   1 GE.
  Non-zero LP elements:      234
  Disk Space:      0K bytes.
  Page Space:    148K bytes.
  Capacity: 29.9% used.
  Estimated Time: 00:02:40

Iter  1[illegible] In [illegible] Out [illegible]
Solution Time:  00:00:33
 Alternate Solutions
```

```
File: TRIAL17                                                      1/03/80 07:
SOLUTION (Minimized): 184828.0422  TEESE TRIAL11
------------------------------------------------------------------------------
  Variable |  Activity     |      Cost       | Variable |  Activity       |
------------------------------------------------------------------------------
I ST.LIGHT   10.650.0000          0.0000 I       PWW   165130.0000
------------------------------------------------------------------------------
|       74        0.0000          0.0000 |  75.0000           0.0000
------------------------------------------------------------------------------
|  76.0000        0.0000          0.0000 |  77.0000           0.0000
------------------------------------------------------------------------------
|  78.0000        0.0000          0.0000 |  79.0000           0.0000
------------------------------------------------------------------------------
|  80.0000        0.0000          0.0000 |  81.0000           0.0000
------------------------------------------------------------------------------
I      FFS   35.942.3600          0.0000 |        85           0.0000
------------------------------------------------------------------------------
I      RMF   64.948.0000          0.0000 I       WMF       1.246.0000
------------------------------------------------------------------------------
I      AMF    1.617.7000          0.0000 I      RAMF      48.170.4800
------------------------------------------------------------------------------
|       88        0.0000          0.0000 |  89.0000           0.0000
------------------------------------------------------------------------------
I      ORE   19.953.1320          0.0000 I      NOFS      15.122.7900
------------------------------------------------------------------------------
```

```
TRIAL17                                                 1/03/80 07:41:48 Page 1-
ON (Minimized): 184828.0422  TEESE TRIAL11
---------------------------------------------------------------------------------
able |  Activity     |      Cost       | Variable |  Activity     |     Cost
---------------------------------------------------------------------------------
 CFS   5,113.5960          0.0000 |           93       0.0000          0.0000
---------------------------------------------------------------------------------
0000         0.0000          0.0000 I        EFS  30,517.6374          0.0000
---------------------------------------------------------------------------------
 ED   767372.4039          0.0000 |           97       0.0000          0.0000
---------------------------------------------------------------------------------
0000         0.0000          0.0000 |  95.0000         0.0000          0.0000
---------------------------------------------------------------------------------
 PH   606170.3228          0.0000 |          101       0.0000          0.0000
---------------------------------------------------------------------------------
 NFS  130465.8830          0.0000 |          103       0.0000          0.0000
---------------------------------------------------------------------------------
0000         0.0000          0.0000 | 105.0000         0.0000          0.0000
---------------------------------------------------------------------------------
0000         0.0000          0.0000 | 107.0000         0.0000          0.0000
---------------------------------------------------------------------------------
IRRI  75.416.8788          0.0000 |          109       0.0000          0.0000
---------------------------------------------------------------------------------
 DCD  150000.0000          0.1000 I LIGHTING  170497.0000          0.0000
---------------------------------------------------------------------------------
TRIAL17                                                 1/03/80 07:41:48 Page 1-
ON (Minimized): 184828.0422  TEESE TRIAL11
---------------------------------------------------------------------------------
able |  Activity     |      Cost       | Variable |  Activity     |     Cost
---------------------------------------------------------------------------------
TING  21,562.0000          0.0000 I  COOKING  68.584.0000          0.0000
---------------------------------------------------------------------------------
 114   5,624.4006          0.0000 I 115.0000  34.606.4954          0.0000
---------------------------------------------------------------------------------
0000   2.023.1609          0.0000 I 117.0000  11,568.9492          0.0000
---------------------------------------------------------------------------------
0000  11.387.8248          0.0000 I 119.0000     940.9017          0.0000
---------------------------------------------------------------------------------
0000  56.841.1664          0.0000 I 121.0000  135235.5990          0.0000
---------------------------------------------------------------------------------
0000   8.883.9800          0.0000 I 123.0000  106493.3277          0.0000
---------------------------------------------------------------------------------
0000       146.6216          0.0000 I 125.0000   2.785.9204          0.0000
---------------------------------------------------------------------------------
0000   9.634.0960          0.0000 I 127.0000  74.349.2400          0.0000
---------------------------------------------------------------------------------
0000  13,876.7057          0.0000 I 129.0000     560.7000          0.0000
---------------------------------------------------------------------------------
0000  14.626.0800          0.0000 I 131.0000  10,919.4750          0.0000
---------------------------------------------------------------------------------
```

```
File: TRIAL17
SOLUTION (Minimized): 184828.0422  TEESE TRIAL11
----------------------------------------------------
! Variable !  Activity    !     Cost      ! Variable
----------------------------------------------------
I 132.0000  24,018.4009          0.0000 I 133.0000
----------------------------------------------------
I 134.0000  34,515.3382          0.0000 I 135.0000
----------------------------------------------------
I 136.0000   6,739.3050          0.0000 I 137.0000
----------------------------------------------------
I 138.0000  11,855.5333          0.0000 I 139.0000
----------------------------------------------------
I 140.0000   2,561.5656          0.0000 I 141.0000
----------------------------------------------------
I 142.0000        73.3108        0.0000 I 143.0000
----------------------------------------------------
I 144.0000       580.0178        0.0000 I 145.0000
----------------------------------------------------
I 146.0000   5,161.9428          0.0000 I 147.0000
----------------------------------------------------
I 148.0000   6,270.2296          0.0000 I 149.0000
----------------------------------------------------
I 150.0000  16,456.2746          0.0000 I 151.0000
----------------------------------------------------
File: TRIAL17
SOLUTION (Minimized): 184828.0422  TEESE TRIAL11
----------------------------------------------------
! Variable !  Activity    !     Cost      ! Variable !
----------------------------------------------------
I 152.0000  426386.7280          0.0000 I 153.0000
----------------------------------------------------
I 154.0000   4,000.0000          0.0000 I 155.0000
----------------------------------------------------
I 156.0000        0.0000         0.0000 I 157.0000
----------------------------------------------------
!    IELEC        0.0000         2.0300 I    GELEC
----------------------------------------------------
I    TELEC  31,012.9096          0.6400 !    NELEC
----------------------------------------------------
!    HELEC  50,000.0000          0.4700 I      163
----------------------------------------------------
I 164.0000  201902.6471          0.0000 I 165.0000
----------------------------------------------------
! 166.0000        0.0000         0.0000 I       MS
----------------------------------------------------
I      168        0.0000         0.0000 I 169.0000
----------------------------------------------------
I 170.0000  24,761.2380          0.0000 I 171.0000
         -------------------------------------------
```

```
TRIAL17                                              1/03/80 07:41:48 Page 1-
ION (Minimized): 184828.0422  TEESE TRIAL11
-------------------------------------------------------------------------------
able |  Activity    |     Cost       | Variable |  Activity    |     Cost
-------------------------------------------------------------------------------
0000   12,705.7909         0.0000 I 173.0000   39,421.4743          0.0000
-------------------------------------------------------------------------------
0000    4,750.7396         0.0000 I     CHAR    4,050.3682          0.0200
-------------------------------------------------------------------------------
DUNG   150258.2532         0.1400 I       CW   105099.7736          0.1100
-------------------------------------------------------------------------------
  FW   442845.0026         0.1070 I      179   290510.9602          0.0000
-------------------------------------------------------------------------------
.0000  314337.7626         0.0000 I 181.0000   137003.4726          0.0000
-------------------------------------------------------------------------------
 COAL  451341.2351         0.0300 I      182    2,785.9204          0.0000
-------------------------------------------------------------------------------
T.GAS  10,316.2236         0.2400 I      HSD   75,087.2340          0.0200
-------------------------------------------------------------------------------
  ATF  10,586.9739         0.0600 I     NAPH   23,908.4978          0.0800
-------------------------------------------------------------------------------
   FO  57,375.3773         0.0200 |      OFF        0.0000          0.0000
-------------------------------------------------------------------------------
  LDO  11,490.1280         0.0100 I      SKO   24,334.9873          0.0100
-------------------------------------------------------------------------------
: TRIAL17                                            1/03/80 07:41:48 Page 1-
MON (Minimized): 184828.0422  TEESE TRIAL11
-------------------------------------------------------------------------------
nable |  Activity    |     Cost       | Variable |  Activity    |     Cost
-------------------------------------------------------------------------------
  LPG   4,014.0185         0.0300 I     IHSD   23,532.5077          0.2200
-------------------------------------------------------------------------------
  IMS       0.0000         0.2100 I     IATF      332.5011          0.2500
-------------------------------------------------------------------------------
INAFH     852.7402         0.2100 |      IFO        0.0000          0.1500
-------------------------------------------------------------------------------
  ICO  100876.1578         0.1200 I     ILDO    1,219.6659          0.2100
-------------------------------------------------------------------------------
 ISKO  15,086.4870         0.2300 I     ILPG      736.7211          0.2100
-------------------------------------------------------------------------------
  202  221423.2969         0.0000 I      203   250876.1578          0.0000
-------------------------------------------------------------------------------
RGANI   6,000.0000         0.0000 | MINERALS    4,428.0000          0.0000
-------------------------------------------------------------------------------
SUGAR  16,471.0000         0.0000 |      GUR   19,564.0000          0.0000
-------------------------------------------------------------------------------
D.OIL  12,016.0000         0.0000 | EDIBLE O   10,899.0000          0.0000
-------------------------------------------------------------------------------
TON T  42,877.0000         0.0000 | TEXT OTH   65,000.0000          0.0000
-------------------------------------------------------------------------------
```

```
File: TRIAL17                                              1/03/80 07:41:48 Pag
SOLUTION (Minimized): 184828.0422  TEESE TRIAL11
--------------------------------------------------------------------------------
! Variable !  Activity    !      Cost       ! Variable !  Activity    !     Cost
--------------------------------------------------------------------------------
!     WOOD  15,000.0000          0.0000 !    PAPER   8,000.0000           0.0
--------------------------------------------------------------------------------
! MANFG MI  60,000.0000          0.0000 ! SYNTHETI  12,000.0000           0.0
--------------------------------------------------------------------------------
!  ORGANIC   1,300.0000          0.0000 ! FERTILIZ  20,000.0000           0.0
--------------------------------------------------------------------------------
! INSECTIC   2,000.0000          0.0000 !    SRUGS  18,000.0000           0.0
--------------------------------------------------------------------------------
! COSMETIC   8,000.0000          0.0000 ! CHEMICAL   9,000.0000           0.0
--------------------------------------------------------------------------------
! REFRACTO   7,000.0000          0.0000 !   CEMENT 400,000.0000           0.0
--------------------------------------------------------------------------------
! NONMETAL  18,000.0000          0.0000 !      I&S  20,000.0000           0.0
--------------------------------------------------------------------------------
! I/SCASTI   5,000.0000          0.0000 ! NON-FERR  13,500.0000           0.0
--------------------------------------------------------------------------------
! METAL PR  25,000.0000          0.0000 ! TRACTORS   4,000.0000           0.0
--------------------------------------------------------------------------------
!  NONELEC  30,000.0000          0.0000 !   MOTORS   2,500.0000           0.0
--------------------------------------------------------------------------------
File: TRIAL17                                              1/03/80 07:41:48 Page
SOLUTION (Minimized): 184828.0422  TEESE TRIAL11
--------------------------------------------------------------------------------
! Variable !  Activity    !      Cost       ! Variable !  Activity    !     Cost
--------------------------------------------------------------------------------
!   CABLES   4,000.0000          0.0000 ! ELECMACH  10,000.0000           0.00
--------------------------------------------------------------------------------
!    SHIPS   1,300.0000          0.0000 ! RAILEQPM   6,500.0000           0.00
--------------------------------------------------------------------------------
! VEHICLES  15,000.0000          0.0000 ! OTHER TR   7,000.0000           0.00
--------------------------------------------------------------------------------
! CONSTRUC  140000.0000          0.0000 ! GAS/WATE   6,785.0000           0.00
--------------------------------------------------------------------------------
! RAILWAYS  19,742.0000          0.0000 ! TRANSOTH  70,000.0000           0.00
--------------------------------------------------------------------------------
! SERVICES  350000.0000          0.0000 !    PADDY  89,267.0000           0.00
--------------------------------------------------------------------------------
!    WHEAT  42,499.0000          0.0000 !  CEREALS  35,970.0000           0.00
--------------------------------------------------------------------------------
!   PULSES  14,036.0000          0.0000 ! SUGARCAN  18,773.0000           0.00
--------------------------------------------------------------------------------
!     JUTE   2,297.0000          0.0000 !   COTTON  14,227.0000           0.00
--------------------------------------------------------------------------------
! PLANTATI  134616.0000          0.0000 ! FOOD MIS  145308.0000           0.00
--------------------------------------------------------------------------------
File: TRIAL17                                              1/03/80 07:41:48 Page 1
SOLUTION (Minimized): 184828.0422  TEESE TRIAL11
--------------------------------------------------------------------------------
! Variable !  Activity    !      Cost       ! Variable !  Activity    !     Cost
--------------------------------------------------------------------------------
! FORESTRY  14,425.0000          0.0000 !  FISHING   9,496.0000           0.00
--------------------------------------------------------------------------------
! FINALDEM  212000.0000          0.0000 !
-----------------------------------------
```

```
 TRIAL17                                               1/03/80 07:41:48 Page 1-11
RAINTS: TEESE TRIAL11
-------------------------------------------------------------------------------------
straint!  Activity   !      RHS       !Constraint!  Activity   !      RHS       !
-------------------------------------------------------------------------------------
GHTING       0.0000 =        0.0000 !  COOLING         0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
EATING       0.0000 =        0.0000 ! ST.LIGHT        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
   PWW       0.0000 =        0.0000 !       EFS       0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
   CFS       0.0000 =        0.0000 !       NFS       0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
   FFS       0.0000 =        0.0000 !      NGFS       0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
   RMF       0.0000 =        0.0000 !      RAMF       0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
   AMF       0.0000 =        0.0000 !       WMF       0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
    PH       0.0000 =        0.0000 !        ED       0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
    DR       0.0000 =        0.0000 !      IRRI       0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
   114       0.0000 =        0.0000 ! 115.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
e: TRIAL17                                              1/03/80 07:41:48 Page 1-12
STRAINTS: TEESE TRIAL11
-------------------------------------------------------------------------------------
nstraint!  Activity   !      RHS       !Constraint!  Activity   !      RHS       !
-------------------------------------------------------------------------------------
116.0000     0.0000 =        0.0000 ! 117.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
118.0000     0.0000 =        0.0000 ! 119.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
120.0000     0.0000 =        0.0000 ! 121.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
122.0000     0.0000 =        0.0000 ! 123.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
24.0000      0.0000 =        0.0000 ! 125.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
126.0000     0.0000 =        0.0000 ! 127.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
128.0000     0.0000 =        0.0000 ! 129.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
130.0000     0.0000 =        0.0000 ! 131.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
132.0000     0.0000 =        0.0000 ! 133.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
134.0000     0.0000 =        0.0000 ! 135.0000        0.0000 =        0.0000 !
-------------------------------------------------------------------------------------
```

```
File: TRIAL17                                         1/03/80 07:41:48 Page 1-
CONSTRAINTS: TEESE TRIAL11
-------------------------------------------------------------------------------
|Constraint|  Activity  |     RHS     |Constraint|  Activity  |     RHS
-------------------------------------------------------------------------------
| 136.0000      0.0000 =      0.0000 | 137.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 138.0000      0.0000 =      0.0000 | 139.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 140.0000      0.0000 =      0.0000 | 141.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 142.0000      0.0000 =      0.0000 | 143.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 144.0000      0.0000 =      0.0000 | 145.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 146.0000      0.0000 =      0.0000 | 147.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 148.0000      0.0000 =      0.0000 | 149.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 150.0000      0.0000 =      0.0000 | 151.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 152.0000      0.0000 =      0.0000 | 153.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
|      158      0.0000 =      0.0000 |      159      0.0000 =      0.0000
-------------------------------------------------------------------------------
File: TRIAL17                                         1/03/80 07:41:48 Page 1-
CONSTRAINTS: TEESE TRIAL11
-------------------------------------------------------------------------------
|Constraint|  Activity  |     RHS     |Constraint|  Activity  |     RHS
-------------------------------------------------------------------------------
| 160.0000      0.0000 =      0.0000 | 161.0000      0.0000 <      0.0000
-------------------------------------------------------------------------------
| 162.0000      0.0000 =      0.0000 | 163.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 164.0000      0.0000 =      0.0000 | 165.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 166.0000      0.0000 =      0.0000 | 167.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 168.0000      0.0000 =      0.0000 | 169.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 170.0000      0.0000 =      0.0000 | 171.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 172.0000      0.0000 =      0.0000 | 173.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
| 174.0000      0.0000 =      0.0000 | 175.0000      0.0000 <      0.0000
-------------------------------------------------------------------------------
| 176.0000      0.0000 <      0.0000 | 177.0000      0.0000 <      0.0000
-------------------------------------------------------------------------------
| 178.0000      0.0000 <      0.0000 | 179.0000      0.0000 =      0.0000
-------------------------------------------------------------------------------
```

```
 TRIAL17                                   1/03/80 07:41:48 Page 1-1
RAINTS: TEESE TRIAL11
------------------------------------------------------------------------------
straint|  Activity  |     RHS     |Constraint|  Activity  |     RHS    |
------------------------------------------------------------------------------
0.0000        0.0000 =      0.0000 | 181.0000        0.0000 =     0.0000 |
------------------------------------------------------------------------------
2.0000        0.0000 <      0.0000 | 183.0000        0.0000 =     0.0000 |
------------------------------------------------------------------------------
4.0000        0.0000 =      0.0000 | 185.0000        0.0000 =     0.0000 |
------------------------------------------------------------------------------
6.0000        0.0000 =      0.0000 |      187        0.0000 =     0.0000 |
------------------------------------------------------------------------------
8.0000        0.0000 =      0.0000 |      190        0.0000 =     0.0000 |
------------------------------------------------------------------------------
91.0000       0.0000 =      0.0000 | 192.0000        0.0000 =     0.0000 |
------------------------------------------------------------------------------
93.0000       0.0000 <      0.0000 | 194.0000        0.0000 <     0.0000 |
------------------------------------------------------------------------------
95.0000       0.0000 <      0.0000 | 196.0000        0.0000 <     0.0000 |
------------------------------------------------------------------------------
97.0000  -12264.9982 <      0.0000 |      199        0.0000 <     0.0000 |
------------------------------------------------------------------------------
00.0000       0.0000 <      0.0000 | 201.0000        0.0000 <     0.0000 |
------------------------------------------------------------------------------
e: TRIAL17                                 1/03/80 07:41:48 Page 1-16
STRAINTS: TEESE TRIAL11
------------------------------------------------------------------------------
nstraint|  Activity  |     RHS     |Constraint|  Activity  |     RHS    |
------------------------------------------------------------------------------
  2,021       0.0000 =      0.0000 I      202        0.0000 =     0.0000 |
------------------------------------------------------------------------------
    203       0.0000 <      0.0000 |
-----------------------------------
tal Error:          0.000000




dating Spreadsheet: C:TRIAL17.WRK(B3VA)
dating Spreadsheet: C:TRIAL17.WRK(B3CA)
dating Spreadsheet: C:TRIAL17.WRK(B3VR)
dating Spreadsheet: C:TRIAL17.WRK(B3CR)
```

# APPENDIX 4.1

## Sample output

```
                    [ [   MULTIPLE REGRESSION   ]]

NOTATIONS USED :

Y: Dependent Variable
X1;X2;... : Independent Variables No.1;No.2;...


NUMBER OF INDEPENDENT VARIABLES :


VARIABLE DETAILS :

Variable    Name                       Unit
Y           Demand                     000s
X1          Price                      in currency


DATA  POINT DETAILS :

1) 1975   2) 1976   3) 1977   4) 1978   5) 1979   6) 1980
7) 1981   8) 1982   9) 1983   10) 1984


DATA LISTING :

Y               X1             DP Id.
100             10             1975
110              9             1976
115              8             1977
120              7             1978
 95             11             1979
 90             12             1980
 80             13             1981
 70             14             1982
 60             15             1983
140              6             1984


REGRESSION TYPE : Linear - Linear


REGRESSION EQUATION :

Y  =  181.3638
      + (-7.939409) *X1
```

```
Y-OBSERVED          Y-CALCULATED          ERROR
100                 101.9697              -1.969711
110                 109.9091               9.088135E-02
115                 117.8485              -2.848526
120                 125.7879              -5.787934
 95                  94.03031               .9696961
 90                  86.09089              3.909104
 80                  78.15149              1.848511
 70                  70.21208              -.2120743
 60                  62.27267             -2.272644
140                 133.7274               6.272644

STATISTICAL PARAMETERS COMPUTED :

Coeficient of determination =  .9793432

Adjusted Coeficient of determination =  .9767612

DW Statistics = 1.473083

F Ration = 379.2824

Sum of Error^2(E^2) = 109.6967

           o
           o
           o

CORRELATION COEFFICIENTS :

Variable-1          Variable-2          Coefficient Value
Y                   Y                    1
X1                  Y                    -.9896
X1                  X1                   1
```

# APPENDIX 6.1

## Sample Output

**LP83 freml.wks**

```
                    o
                    o
                    o

                    .
Warning: Read Section 1 regarding WORKFILES
..TITLE
  (83TITLE)
     Title: RURAL ENERGY DATA

..OBJECTIVE
  (83VARIABLE)
  (83COST)
     Objective: MINIMIZED Variables:    110
          0.0000 X1.1
          0.0000 X1,2
          0.0000 X1,3
          0.2200 X3,4
          0.2200 X3,5
          0.2200 X3,6
          0.4200 X3,10
          0.4200 X3,11
          0.4000 X8,10
          0.4000 X8,11
          0.5300 X1,12
          0.4900 X2,12
          0.5900 X3,13
          0.6700 X6,14
          0.6000 X4,15
          0.6000 X5,15
          1.5000 X13,16
          0.4000 X7,18
          0.6700 X6,19
          0.4000 X7,20
          1.5000 X13,21
          0.4000 X8,22
          0.7300 X8,23
          0.7300 X8,24
          0.4000 X7,25
          0.4000 X7,26
          0.4000 X7,27
          0.4400 X8,34
          0.4400 X8,35
          0.4400 X8,38
          0.4000 X7,37
          0.4000 X7,39
          0.0000 Y1,13
          0.0000 Y2,13
          0.0000 Y3,13
          0.0000 Y10,7
          0.0000 A10,7
          0.0000 Z10,7
          0.0000 Y4,4
          0.0000 Y5,4
          0.0000 Y6,4
          0.0000 Y11,7
          0.0000 A11,7
     0.0000  Z11,7
     0.0000  Y22,4
     0.0000  Y23,4
     0.0000  Y24,4
     0.0000  Y25,4
     0.0000  Y26,4
     0.0000  Y27,4
     0.0000  Y28,4
     0.0000  Y29,4
     0.0000  Y37,5
     0.0000  Y38,5
     0.0000  Y39.5
     0.0000  Y34,6
     0.0000  Y35,6
     0.0000  Y36.6
     0.0000  Y34,7
     0.0000  Y36.7
     0.0000  Y12,1
     0.0000  Y12,3
     0.0000  Y13,1
     0.0000  Y13,3
     0.0000  Y14,1
     0.0000  Y14,3
     0.0000  Y15.1
     0.0000  Y15,3
     0.0000  Y16.1
     0.0000  Y16,3
     0.0000  Y17.1
     0.0000  Y18,3
     0.0000  Y33,3
     0.0000  Y19,2
     0.0000  Y20,2
     0.0000  Y21,2
     0.0000  Y0,7
   700.0000  Y1
 2,533.0000  Y2
 7,085.0000  Y3
 7,520.0000  Y4
14,790.0000  Y5
31,750.0000  Y6
 4,970.0000  Y10
 8,800.0000  Y11
    12.5000  Y12
    12.5000  Y13
    12.5000  Y14
    12.5000  Y15
    62.5000  Y16
   150.0000  Y17
    15.0000  Y18
    12.5000  Y19
    12.5000  Y20
    70.0000  Y21
 2.420.0000  Y22
 3,000.0000  Y23
 4,335.0000  Y24
 2,000.0000  Y25
 2,500.0000  Y26
12,000.0000  Y27
10,000.0000  Y28
18,615.0000  Y29
   150.0000  Y33
30,000.0000  Y34
37,500.0000  Y35
 1,500.0000  Y36
 2,250.0000  Y37
10,000.0000  Y38
 7,500.0000  Y39
```

```
..BOUNDS
  (83LOWER)
  (83UPPER)
    Lower & Upper Bounds
          0.0000 <= Y2        <=     2.0000
          0.0000 <= Y3        <=     2.0000
          0.0000 <= Y5        <=     2.0000
          0.0000 <= Y6        <=     2.0000
          0.0000 <= Y14       <=    10.0000
          0.0000 <= Y15       <=    10.0000
          0.0000 <= Y17       <=    60.0000
          0.0000 <= Y18       <=    10.0000
          0.0000 <= Y19       <=    10.0000
          0.0000 <= Y20       <=   130.0000
          0.0000 <= Y21       <=   130.0000
          0.0000 <= Y23       <=     3.0000
          0.0000 <= Y24       <=     3.0000
          0.0000 <= Y26       <=     5.0000
          0.0000 <= Y27       <=     5.0000
          0.0000 <= Y29       <=     6.0000
          0.0000 <= Y33       <=   130.0000
          0.0000 <= Y35       <=     2.0000
          0.0000 <= Y36       <=   350.0000
..CONSTRAINTS
  (83CONSTRAINT)
    Row:  RM1        Elements:   4
            1.0000 X1,1
            1.0000 X1,2
            1.0000 X1,3
            1.0000 X1,12     <=2373030.000

    Row:  RM2        Elements:   1
            1.0000 X2,12     <=1898424.000

    Row:  RM3        Elements:   6
            1.0000 X3,4
            1.0000 X3,5
            1.0000 X3,6
            1.0000 X3,10
            1.0000 X3,11
            1.0000 X3,13     <=300000.0000

    Row:  RM4        Elements:   1
            1.0000 X4,15     <=100000.0000

    Row:  RM5        Elements:   1
            1.0000 X5,15     <=100000.0000

    Row:  RM6        Elements:   2
            1.0000 X6,14
            1.0000 X6,19     <=118651.5000
```

```
Row:  RM7          Elements:    8
          1.0000  X7,18
          1.0000  X7,20
          1.0000  X7,25
          1.0000  X7,26
          1.0000  X7,27
          1.0000  X7,37
         -1.0000  Y10,7
         -1.0000  Y11,7       <=10.000.0000

Row:  RM8          Elements:    8
          1.0000  X8.10
          1.0000  X8,11
          1.0000  X8,22
          1.0000  X8.23
          1.0000  X8.24
          1.0000  X8.34
          1.0000  X8.35
          1.0000  X8.38       <=20.000.0000

Row:  DD1          Elements:    6
          1.0000  Y12.1
          1.0000  Y13.1
          1.0000  Y14,1
          1.0000  Y15.1
          1.0000  Y16.1
          1.0000  Y17,1       >=239020.0000

Row:  DD2          Elements:    6
          1.0000  Y12,3
          1.0000  Y13,3
          1.0000  Y14,3
          1.0000  Y15,3
          1.0000  Y16.3
          1.0000  Y18,3       >=65.000.0000

Row:  DD3          Elements:    3
          1.0000  Y19,2
          1.0000  Y20.2
          1.0000  Y21,2       >=70.000.0000

Row:  DD4          Elements:   11
          1.0000  Y4.4
          1.0000  Y5.4
          1.0000  Y6.4
          1.0000  Y22.4
          1.0000  Y23,4
          1.0000  Y24,4
          1.0000  Y25,4
          1.0000  Y26,4
          1.0000  Y27,4
          1.0000  Y28,4
          1.0000  Y29,4       >=366373.0000
```

```
Row:  DD5          Elements:    3
            1.0000 Y37,5
            1.0000 Y38,5
            1.0000 Y39,5       >=37,000.0000

Row:  DD6          Elements:    3
            1.0000 Y34,6
            1.0000 Y35,6
            1.0000 Y36.6       >=152455.0000

Row:  DD7          Elements:    2
            1.0000 Y34,7
            1.0000 Y36,7       >=15,245.0000

Row:  EB1          Elements:    2
           0.6000 X1,1
          -1.0000 Y1,13        =            0.0000

Row:  EB2          Elements:    2
           0.6000 X1,2
          -1.0000 Y2.13        =            0.0000

Row:  EB3          Elements:    2
           0.6000 X1.3
          -1.0000 Y3.13        =            0.0000

Row:  EB4          Elements:    5
          _1.0000 X13.16__
           1.0000 X13.21
          -1.0000 Y1.13
          --1.0000 Y2.13
          -1.0000 Y3.13        =            0.0000

Row:  EB5          Elements:    2
           0.7000 X13.16
          -1.0000 Y16.1
          -1.0000 Y16.2        =            0.0000

Row:  EB6          Elements:    2
           0.7000 X13.21
          -1.0000 Y21.2        =            0.0000

Row:  EB7          Elements:    2
           0.8000 X3.4
          -1.0000 Y4.4         =            0.0000

Row:  EB8          Elements:    2
           0.8000 X3.5
          -1.0000 Y5.4         =            0.0000

Row:  EB9          Elements:    2
           0.8000 X3,6
          -1.0000 Y6,4         =            0.0000

Row:  E10          Elements:    2
           0.7500 X7,39
          -1.0000 Y39,5        =            0.0000
```

```
Row:  E11         Elements:    2
        0.8000  X3.10
       -1.0000  A10,7      =          0.0000

Row:  E12         Elements:    2
        0.8000  X3,11
       -1.0000  A11,7      =          0.0000

Row:  E13         Elements:    2
        0.5000  X8,22
       -1.0000  Y22.4      =          0.0000

Row:  E14         Elements:    2
        0.7000  X8.10
       -1.0000  Z10.7      =          0.0000

Row:  E15         Elements:    2
        0.7000  X8,11
       -1.0000  Z11,7      =          0.0000

Row:  E16         Elements:    3
       -1.0000  Y10,7
        1.0000  A10,7
        1.0000  Z10,7      =          0.0000

Row:  E17         Elements:    3
       -1.0000  Y11,7
        1.0000  A11,7
        1.0000  Z11,7      =          0.0000

Row:  E18         Elements:

                               2
        0.5000  X8.23
       -1.0000  Y23,4      =          0.0000

Row:  E19         Elements:    2
        0.5000  X8,24
       -1.0000  Y24.4      =          0.0000

Row:  E20         Elements:    2
        0.6000  X7.25
       -1.0000  Y25.4      =          0.0000

Row:  E21         Elements:    2
        0.6000  X7,26
       -1.0000  Y26,4      =          0.0000
```

```
Row:  E22          Elements:     2
          0.6000  X7,27
         -1.0000  Y27.4      =          0.0000

Row:  E23          Elements:     2
          1.0000  X7,20
         -1.0000  Y20,2      =          0.0000

Row:  E24          Elements:     4
          0.2000  X1,12
          0.2000  X2,12
         -1.0000  Y12.1
         -1.0000  Y12.3      =          0.0000

Row:  E25          Elements:     3
          0.3000  X3,13
         -1.0000  Y13,1
         -1.0000  Y13,3      =          0.0000

Row:  E26          Elements:     3
          0.4000  X6,14
         -1.0000  Y14.1
         -1.0000  Y14,3      =          0.0000

Row:  E27          Elements:     4
          0.2500  X4,15
          0.2500  X5,15
         -1.0000  Y15.1
         -1.0000  Y15,3      =          0.0000

Row:  E28          Elements:     3
          0.7000  X13.16
         -1.0000  Y16.1
         -1.0000  Y16.3      =          0.0000

Row:  E29          Elements:     2
          0.7500  X7,18
         -1.0000  Y18,3      =          0.0000

Row:  E30          Elements:     2
          0.3500  X6.19
         -1.0000  Y19,2      =          0.0000

Row:  E31          Elements:     4
          0.6000  X13,21
          1.0000  Y1,13
          1.0000  Y3,13
          1.0000  Y21,2      =          0.0000
```

```
Row:  E32          Elements:     3
         0.6000  X8,34
        -1.0000  Y36,6
        -1.0000  Y34,7      =          0.0000

Row:  E33          Elements:     2
         0.6000  X8,35
        -1.0000  Y35,6      =          0.0000

Row:  E34          Elements:     2
         0.6000  X8,38
        -1.0000  Y38,5      =          0.0000

Row:  E35          Elements:     2
         0.7500  X7,37
        -1.0000  Y37,5      =          0.0000

Row:  E36          Elements:     7
        -1.0000  X7,20
        -1.0000  X7,25
        -1.0000  X7,26
        -1.0000  X7,27
         1.0000  Y10,7
         1.0000  Y11,7
         1.0000  Y0,7       =          0.0000

Row:  C17          Elements:     2
         1.0000  Y17.1
      -600.0000  Y17         <=        0.0000

Row:  C33          Elements:     2
         1.0000  Y33.3
      -174.0000  Y33         <=        0.0000

Row:  C36          Elements:     3
         1.0000  Y36.6
         1.0000  Y36,7
    -1,225.0000  Y36         <=        0.0000

Row:  CP1          Elements:     2
         1.0000  Y1,13
    -4,986.0000  Y1          <=        0.0000

Row:  CP2          Elements:     2
         1.0000  Y2,13
    -24930.0000  Y2          <=        0.0000

Row:  CP3          Elements:     2
         1.0000  Y3,13
    -84763.2000  Y3          <=        0.0000

Row:  CP4          Elements:     2
         1.0000  Y4,4
    -5,968.0000  Y4          <=        0.0000
```

```
Row:  CP5            Elements:     2
           1.0000  Y5,4
   -17904.0000  Y5              <=          0.0000

Row:  CP6            Elements:     2
           1.0000  Y6,4
   -41776.0000  Y6              <=          0.0000

Row:  C10            Elements:     2
           1.0000  Y10,7
   -8,000.0000  Y10             <=          0.0000

Row:  C11            Elements:     2
           1.0000  Y11,7
   -16000.0000  Y11             <=          0.0000

Row:  C22            Elements:     2
           1.0000  Y22.4
   -2,700.0000  Y22             <=          0.0000

Row:  C23            Elements:     2
           1.0000  Y23,4
   -4,320.0000  Y23             <=          0.0000

Row:  C24            Elements:     2
           1.0000  Y24,4
   -5,400.0000  Y24             <=          0.0000

Row:  C25            Elements:     2
           1.0000  Y25.4
   -1,440.0000  Y25             <=          0.0000

Row:  C26            Elements:     2
           1.0000  Y26,4
   -2,400.0000  Y26             <=          0.0000

Row:  C27            Elements:     2
           1.0000  Y27,4
   -3,780.0000  Y27             <=          0.0000

Row:  C28            Elements:     2
           1.0000  Y28,4
   -2,400.0000  Y28             <=          0.0000

Row:  C29            Elements:     2
           1.0000  Y29,4
   -2.880.0000  Y29             <=          0.0000

Row:  C34            Elements:     3
           1.0000  Y34,6
           1.0000  Y34,7
   -9,400.0000  Y34             <=          0.0000

Row:  C35            Elements:     2
           1.0000  Y35,6
   -14770.5000  Y35             <=          0.0000
```

```
Row:  C36          Elements:     3
              1.0000  Y36,6
              1.0000  Y36,7
    -362556.000  Y36         <=          0.0000

Row:  C37          Elements:     2
              1.0000  Y37,5
    -1,080.0000  Y37         <=          0.0000

Row:  C38          Elements:     2
              1.0000  Y38.5
    -3.222.4000  Y38         <=          0.0000

Row:  C39          Elements:     2
              1.0000  Y39,5
    -2,416.8000  Y39         <=          0.0000

Row:  C12          Elements:     3
              1.0000  Y12.1
              1.0000  Y12,3
    -3,000.0000  Y12         <=          0.0000

Row:  C13          Elements:     3
              1.0000  Y13.1
              1.0000  Y13,3
    -3,000.0000  Y13         <=          0.0000

Row:  C14          Elements:     3
              1.0000  Y14.1
              1.0000  Y14.3
    -3,000.0000  Y14         <=          0.0000

Row:  C15          Elements:     3
              1.0000  Y15.1
              1.0000  Y15,3
    -3.000.0000  Y15         <=          0.0000

Row:  C16          Elements:     3
              1.0000  Y16.1
              1.0000  Y16.3
    -3,000.0000  Y16         <=          0.0000

Row:  C18          Elements:     2
              1.0000  Y18.3
      -770.0000  Y18         <=          0.0000

Row:  C19          Elements:     2
              1.0000  Y19,2
      -500.0000  Y19         <=          0.0000

Row:  C20          Elements:     2
              1.0000  Y20,2
      -500.0000  Y20         <=          0.0000

Row:  C21          Elements:     2
              1.0000  Y21,2
      -500.0000  Y21         <=          0.0000
```

```
..ACTIVITY
  (83VA)
  (83CA)
..REDUCEDCOS
  (83VR)
  (83CR)

Statistics-
  LP83 Version 5.00
  Machine memory:  640K bytes.
  Pagable memory:  431K bytes.
  Variables:       110
  Constraints:      85
    42 LE,  36 EQ,   7 GE.
  Non-zero LP elements:     234
  Disk Space:      0K bytes.
  Page Space:     78K bytes.
  Capacity: 22.6% used.
  Estimated Time: 00:01:07

 Iter     ■ In X[illegible]    Out E[illegible]
```

```
File: Freml                                            1/01/80 00:35:19 Page
SOLUTION (Minimized): 2157177.421  RURAL ENERGY DATA
----------------------------------------------------------------------------
¦ Variable ¦  Activity    ¦     Cost     ¦ Variable ¦  Activity    ¦    Cost
----------------------------------------------------------------------------
¦     X1,1         0.0000        0.0000 I      X1,2  83,100.0000        0.00
----------------------------------------------------------------------------
¦     X1,3         0.0000        0.0000 I      X3,4  99,550.0000        0.22
----------------------------------------------------------------------------
I     X3,5  44,760.0000        0.2200 I      X3,6  104440.0000        0.22
----------------------------------------------------------------------------
¦    X3,10         0.0000        0.4200 I     X3,11  51,250.0000        0.42
----------------------------------------------------------------------------
¦    X8,10         0.0000        0.4000 I     X8,11  20,000.0000        0.40
----------------------------------------------------------------------------
¦    X1,12         0.0000        0.5300 I     X2,12  865590.0000        0.49
----------------------------------------------------------------------------
I    X3,13         0.0000        0.5900 I     X6,14  75,000.0000        0.67
----------------------------------------------------------------------------
I    X4,15  100000.0000        0.6000 I     X5,15  20,000.0000        0.60
----------------------------------------------------------------------------
I   X13,16  49,860.0000        1.5000 ¦     X7,18        0.0000        0.400
----------------------------------------------------------------------------
I    X6,19  14,285.7143        0.6700 I     X7,20  65,000.0000        0.40
----------------------------------------------------------------------------
File: Freml
```

```
ION (Minimized): 2157177.421  RURAL ENERGY DATA          1/01/80 00:35:19 Page 1-
------------------------------------------------------------------------------------
iable !  Activity     !     Cost        ! Variable !  Activity     !     Cost
------------------------------------------------------------------------------------
13,21        0.0000          1.5000 I    X8,22          0.0000          0.4000 !
------------------------------------------------------------------------------------
X8,23        0.0000          0.7300 I    X8,24          0.0000          0.7300 !
------------------------------------------------------------------------------------
X7,25        0.0000          0.4000 I    X7.26          0.0000          0.4000 !
------------------------------------------------------------------------------------
X7,27        0.0000          0.4000 I    X8,34          0.0000          0.4400 !
------------------------------------------------------------------------------------
X8,35        0.0000          0.4400 I    X8,38          0.0000          0.4400 !
------------------------------------------------------------------------------------
X7,37        0.0000          0.4000 I    X7,39     49.333.3333          0.4000 !
------------------------------------------------------------------------------------
Y1,13        0.0000          0.0000 I    Y2.13     49.860.0000          0.0000 !
------------------------------------------------------------------------------------
Y3,13        0.0000          0.0000 I    Y10,7          0.0000          0.0000 !
------------------------------------------------------------------------------------
A10,7        0.0000          0.0000 I    Z10,7          0.0000          0.0000 !
------------------------------------------------------------------------------------
 Y4,4   79.640.0000          0.0000 I     Y5,4     35.808.0000          0.0000 !
------------------------------------------------------------------------------------
: Frem1                                               1/01/80 00:35:19 Page 1-3
TION (Minimized): 2157177.421  RURAL ENERGY DATA
------------------------------------------------------------------------------------
riable !  Activity     !     Cost        ! Variable !  Activity     !     Cost     !
------------------------------------------------------------------------------------
 Y6,4   83,552.0000          0.0000 I    Y11,7     55.000.0000          0.0000 !
------------------------------------------------------------------------------------
A11,7   41,000.0000          0.0000 I    Z11,7     14.000.0000          0.0000 !
------------------------------------------------------------------------------------
Y22,4        0.0000          0.0000 !    Y23.4          0.0000          0.0000 !
------------------------------------------------------------------------------------
Y24,4        0.0000          0.0000 !    Y25,4          0.0000          0.0000 !
------------------------------------------------------------------------------------
Y26,4        0.0000          0.0000 !    Y27,4          0.0000          0.0000 !
------------------------------------------------------------------------------------
Y28,4   167373.0000          0.0000 I    Y29.4          0.0000          0.0000 !
------------------------------------------------------------------------------------
Y37,5        0.0000          0.0000 !    Y38.5          0.0000          0.0000 !
------------------------------------------------------------------------------------
Y39,5   37,000.0000          0.0000 I    Y34,6     152455.0000          0.0000 !
------------------------------------------------------------------------------------
Y35,6        0.0000          0.0000 !    Y36.6          0.0000          0.0000 !
------------------------------------------------------------------------------------
Y34,7        0.0000          0.0000 I    Y36.7     15,245.0000          0.0000 !
------------------------------------------------------------------------------------
: Frem1
```

```
                                               1/01/80 00:35:19 Pag
SOLUTION (Minimized): 2157177.421  RURAL ENERGY DATA
-----------------------------------------------------------------------
| Variable |  Activity    |     Cost      | Variable |  Activity    |    Cost
-----------------------------------------------------------------------
I    Y12,1   108118.0000        0.0000 I    Y12,3  65,000.0000        0.0
-----------------------------------------------------------------------
|    Y13,1        0.0000        0.0000 |    Y13,3       0.0000        0.00
-----------------------------------------------------------------------
I    Y14,1   30,000.0000        0.0000 |    Y14,3       0.0000        0.00
-----------------------------------------------------------------------
I    Y15,1   30,000.0000        0.0000 |    Y15,3       0.0000        0.00
-----------------------------------------------------------------------
I    Y16,1   34,902.0000        0.0000 |    Y16,3       0.0000        0.00
-----------------------------------------------------------------------
I    Y17,1   36,000.0000        0.0000 I    Y18,3       0.0000        0.00
-----------------------------------------------------------------------
|    Y33,3        0.0000        0.0000 I    Y19,2   5,000.0000        0.00
-----------------------------------------------------------------------
I    Y20,2   65,000.0000        0.0000 I    Y21,2       0.0000        0.00
-----------------------------------------------------------------------
I     Y0,7   10,000.0000        0.0000 |       Y1       0.0000      700.00
-----------------------------------------------------------------------
|       Y2        2.0000    2,533.0000 I       Y3       0.0000    7,085.00
-----------------------------------------------------------------------
File: Frem1                                    1/01/80 00:35:19 Page
SOLUTION (Minimized): 2157177.421  RURAL ENERGY DATA
-----------------------------------------------------------------------
| Variable |  Activity    |     Cost      | Variable |  Activity    |    Cost
-----------------------------------------------------------------------
I       Y4       13.3445    7,520.0000 |       Y5       2.0000   14,790.00
-----------------------------------------------------------------------
|       Y6        2.0000   31,750.0000 I      Y10       0.0000    4,970.00
-----------------------------------------------------------------------
I      Y11        3.4375    8,800.0000 I      Y12      57.7060       12.50
-----------------------------------------------------------------------
I      Y13        0.0000       12.5000 |      Y14      10.0000       12.50
-----------------------------------------------------------------------
|      Y15       10.0000       12.5000 I      Y16      11.6340       62.50
-----------------------------------------------------------------------
|      Y17       60.0000      150.0000 I      Y18       0.0000       15.00
-----------------------------------------------------------------------
|      Y19       10.0000       12.5000 I      Y20     130.0000      12.500
-----------------------------------------------------------------------
|      Y21        0.0000       70.0000 |      Y22       0.0000   2,420.000
-----------------------------------------------------------------------
|      Y23        0.0000    3,000.0000 |      Y24       0.0000   4,335.000
-----------------------------------------------------------------------
|      Y25        0.0000    2,000.0000 |      Y26       0.0000   2,500.000
-----------------------------------------------------------------------
File: Frem1
```

```
Frem1                                                   1/01/80 01:08:50 Page 1
ION (Minimized): 2157177.421  RURAL ENERGY DATA
--------------------------------------------------------------------------------
iable ¦  Activity    ¦     Cost       ¦ Variable ¦  Activity    ¦     Cost
--------------------------------------------------------------------------------
  Y27        0.0000    12,000.0000 I       Y28        69.7387    10,000.0000
--------------------------------------------------------------------------------
  Y29        0.0000    18,615.0000 ¦       Y33         0.0000       150.0000
--------------------------------------------------------------------------------
  Y34       16.2186    20,000.0000 ¦       Y35         0.0000    37,500.0000
--------------------------------------------------------------------------------
  Y36       12.4449     1,500.0000 ¦       Y37         0.0000     2,250.0000
--------------------------------------------------------------------------------
  Y38        0.0000    10,000.0000 I       Y39        15.3095     7,500.0000
--------------------------------------------------------------------------------
```

```
le: Frem1                                          1/01/80 00:35:19 Page 1-7
STRAINTS: RURAL ENERGY DATA
-------------------------------------------------------------------------------
nstraint¦  Activity    ¦     RHS      ¦Constraint¦  Activity    ¦     RHS      ¦
-------------------------------------------------------------------------------
     RM1  83,100.0000  <2373030.000  I       RM2  865590.0000  <1898424.000  ¦
-------------------------------------------------------------------------------
     RM3  300000.0000  <300000.0000  ¦       RM4  100000.0000  <100000.0000  ¦
-------------------------------------------------------------------------------
     RM5  20,000.0000  <100000.0000  I       RM6  89,285.7143  <118651.5000  ¦
-------------------------------------------------------------------------------
     RM7  10,000.0000  <10,000.0000  ¦       RM8  20,000.0000  <20,000.0000  ¦
-------------------------------------------------------------------------------
     DD1  239020.0000  >239020.0000  ¦       DD2  65,000.0000  >65,000.0000  ¦
-------------------------------------------------------------------------------
     DD3  70,000.0000  >70,000.0000  ¦       DD4  366373.0000  >366373.0000  ¦
-------------------------------------------------------------------------------
     DD5  37,000.0000  >37,000.0000  ¦       DD6  152455.0000  >152455.0000  ¦
-------------------------------------------------------------------------------
     DD7  15,245.0000  >15,245.0000  ¦       EB1       0.0000  =      0.0000  ¦
-------------------------------------------------------------------------------
     EB2       0.0000  =      0.0000  ¦       EB3       0.0000  =      0.0000  ¦
-------------------------------------------------------------------------------
     EB4       0.0000  =      0.0000  ¦       EB5       0.0000  =      0.0000  ¦
-------------------------------------------------------------------------------
```

```
File: Freml                                      1/01/80 00:35:19 Page
CONSTRAINTS: RURAL ENERGY DATA
----------------------------------------------------------------------------
!Constraint!  Activity  !      RHS      !Constraint!  Activity  !      RHS
----------------------------------------------------------------------------
!      EB6      0.0000 =      0.0000 !      EB7      0.0000 =      0.000
----------------------------------------------------------------------------
!      EB8      0.0000 =      0.0000 !      EB9      0.0000 =      0.000
----------------------------------------------------------------------------
!      E10      0.0000 =      0.0000 !      E11      0.0000 =      0.000
----------------------------------------------------------------------------
!      E12      0.0000 =      0.0000 !      E13      0.0000 =      0.000
----------------------------------------------------------------------------
!      E14      0.0000 =      0.0000 !      E15      0.0000 =      0.000
----------------------------------------------------------------------------
!      E16      0.0000 =      0.0000 !      E17      0.0000 =      0.000
----------------------------------------------------------------------------
!      E18      0.0000 =      0.0000 !      E19      0.0000 =      0.000
----------------------------------------------------------------------------
!      E20      0.0000 =      0.0000 !      E21      0.0000 =      0.000
----------------------------------------------------------------------------
!      E22      0.0000 =      0.0000 !      E23      0.0000 =      0.000
----------------------------------------------------------------------------
!      E24      0.0000 =      0.0000 !      E25      0.0000 =      0.000
----------------------------------------------------------------------------
File: Freml                                      1/01/80 00:35:19 Page
CONSTRAINTS: RURAL ENERGY DATA
----------------------------------------------------------------------------
!Constraint!  Activity  !      RHS      !Constraint!  Activity  !      RHS
----------------------------------------------------------------------------
!      E26      0.0000 =      0.0000 !      E27      0.0000 =      0.000
----------------------------------------------------------------------------
I      E28      0.0000 =      0.0000 !      E29      0.0000 =      0.000
----------------------------------------------------------------------------
!      E30      0.0000 =      0.0000 !      E31      0.0000 =      0.000
----------------------------------------------------------------------------
!      E32      0.0000 =      0.0000 !      E33      0.0000 =      0.000
----------------------------------------------------------------------------
!      E34      0.0000 =      0.0000 !      E35      0.0000 =      0.000
----------------------------------------------------------------------------
!      E36      0.0000 =      0.0000 !      C17      0.0000 <      0.000
----------------------------------------------------------------------------
I      C33      0.0000 <      0.0000 !      C36      0.0000 <      0.000
----------------------------------------------------------------------------
I      CP1      0.0000 <      0.0000 !      CP2      0.0000 <      0.000
----------------------------------------------------------------------------
!      CP3      0.0000 <      0.0000 !      CP4      0.0000 <      0.000
----------------------------------------------------------------------------
!      CP5      0.0000 <      0.0000 !      CP6      0.0000 <      0.000
----------------------------------------------------------------------------
```

```
e: Freml                                            1/01/80 00:35:19 Page 1-10
STRAINTS: RURAL ENERGY DATA
------------------------------------------------------------------------------
nstraint!  Activity  !      RHS      !Constraint!  Activity  !      RHS      !
------------------------------------------------------------------------------
    C10          0.0000 <      0.0000 !     C11         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C22          0.0000 <      0.0000 I     C23         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C24          0.0000 <      0.0000 I     C25         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C26          0.0000 <      0.0000 I     C27         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C28          0.0000 <      0.0000 !     C29         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C34          0.0000 <      0.0000 I     C35         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C36     -4496727.42 <      0.0000 I     C37         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C38          0.0000 <      0.0000 !     C39         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C12          0.0000 <      0.0000 !     C13         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C14          0.0000 <      0.0000 !     C15         0.0000 <      0.0000 !
------------------------------------------------------------------------------
e: Freml                                            1/01/80 00:35:19 Page 1-11
STRAINTS: RURAL ENERGY DATA
------------------------------------------------------------------------------
nstraint!  Activity  !      RHS      !Constraint!  Activity  !      RHS      !
------------------------------------------------------------------------------
    C16          0.0000 <      0.0000 !     C18         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C19          0.0000 <      0.0000 !     C20         0.0000 <      0.0000 !
------------------------------------------------------------------------------
    C21          0.0000 <      0.0000 !
--------------------------------------
tal Error:            0.000000

    84 In Y14.3
```

# GLOSSARY

| | | |
|---|---|---|
| AFR | - | Annual fuel replacement. |
| Biogas plant | - | A device to produce methane gas and fertiliser from animal wastes through controlled decomposition. |
| Calorific value | - | Amount of energy contained in a substance per unit mass (Kcal/kg). |
| Coefficient matrix | - | A matrix giving the input requirements per unit of output which is derived from the input-output transactions table by dividing the elements in the $n^{th}$ column representing inputs by the summation over the $n^{th}$ row in the I/O and in the final demands vector representing output. |
| Coefficient of determination | - | The ratio of explained variation to total variation. |
| Computer | - | A device that receives, processes and presents information; of two basic types, analog and digital. |
| Conventional technology | - | The current technology in practice. |
| Correlation coefficient | - | Degree of linear relationship between the two variables. |
| Data point | - | Individual data in a data set. |
| Degree days | - | A meteorological concept used to calculate heating load. |
| Demand vector | - | A vector of end use demands in Input-Output model. |
| Disk/Diskette | - | High-Speed computer input-output medium in which data are magnetically recorded. Circular in shape in a square cover (8", 5.1/4" or 3.1/2"). |

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| Drive (Disk Drive) | An unit that spins the disk at 2400-3600 revolutions per minute. Also contains magnetic read/write heads mounted on a comb-like access mechanism that moves radially to read and record information on them. |
| DW statistics | Durbin-Watson Statistic- a statistic to determine the presence of serial correlation in a data set. |
| Elasticity | Gives the percentage change in variable-X with reference to a unit percent change in variable-Y. |
| Floppy | See Disk/Diskette. |
| F Ratio | A statistic used to test the null hypothesis that the multiple correlation zero in the population from which the sample was drawn. |
| FRR | Fuel Replacement Ratio gives the ratio of fuel type-Y required to replace a given quantity of fuel type-X. |
| Fuel oil boiler | An industrial boiler using furnace oil as a fuel. |
| Gasifier (Biomass) | A device to produce carbon monoxide, carbon dioxide, hydrogen and nitrogen through partial combustion and reduction. |
| Geyser (electric) | A conventional electric water heating device. |
| Gross output vector | Is the vector of gross outputs in each sector of the economy. |
| GSR | Global Solar Radiation. |
| Hard disc | A sealed magnetic storage medium in the computer with a high capacity (more than 10 Mbytes). |
| Hardware | The actual physical parts in a computer. |
| Hp | Horse power. |
| IBM PC, PC/XT, PC/AT | Different micro-computer models released by International Business Machines, USA. |

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|---|---|---|
| IRR | - | The Internal Rate of Return is that rate of interest at which the present value of net cashflows equals zero. |
| K bytes | - | Kilo bytes. |
| Kg, Kgm | - | Kilograms. |
| KWhr | - | Kilo watt hour. |
| Lotus 1-2-3 | - | A Spreadsheet computer program developed by LOTUS Development Corporation, USA. |
| LP83 | - | A linear programming software package developed by Sunset Software , USA for use on microcomputers. |
| Marginal values | - | The value of an incremental unit. |
| Math co-processor (80287/8087) | - | An Integrated Circuit (IC) chip to be added to the IBM/PC to enhance the execution speed. |
| MLR | - | Multiple linear regression. |
| Monochrome terminal | - | A black and white screen to display the user-computer communication. |
| Motive power | - | The energy required to move an object over a certain distance. |
| Conversion efficiency | - | The efficiency with which an energy form is being converted to a secondary form of energy. |
| MS-DOS | - | A master program known as Microsoft Disk Operating System to manage the basic computer operations. On IBM/PC's it is called as PC-DOS. |
| Network optimization | - | Optimisation of originating flows across a network of interactive chains. |
| Network balance-equations | - | Equations linking flows along a network with the help of simple mathematical functions (addition, subtraction). |
| PC-DOS | - | Refer MS-DOS. |

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| Photovoltaic arrays | - | Solar cells fixed on a rectangular panel. |
| Program/ Software | - | A set of instructions written in one of the computer languages to perform a specific task. |
| PW | - | Peak watt. |
| Renewable technology | - | The techniques of utilizing those primary energy sources which, for practical purposes, can be considered inexhaustible, e.g. solar power, wind, geothermal, hydroelectricity. |
| Resource allocation model | - | A model to study the tradeoffs between investments in the energy sector vis-a-vis the non-energy sectors. |
| Rotors (sail type) | - | A form of rotor for a wind energy machine, with a vertical axis: its advantage is that it does not have to face the direction of the wind. |
| Rural energy model | - | A model to study the demand-supply aspects of energy in a rural setting. |
| Solar photovoltaic cell | - | A device for converting the energy of solar radiation into electrical power directly. |
| Solar thermal | - | Pertaining to the heat of the Sun. |
| Spread sheet | - | A computer program to tabulate data and perform arithmetic and scientific operations. |
| Thermal conductivity | - | A physical constant of a material indicating its readiness to conduct heat. |
| Transaction matrix | - | A matrix which gives the distribution of the outputs of various sectors over all the sectors of the economy for intermediate consumption as well as for final demand purposes. |
| Trombe wall | - | An architectural idea on which a solar heating system can be based. |